POWER PLANT ENGINEERING

Established Over 30 Years

VOL. XXX CHICAGO, OCTOBER 15, 1926 No. 20

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Published on the 1st and 15th of each Month by the
Technical Publishing Co., 53 West Jackson Blvd., Chicago
New York Office, 150 Nassau Street

Subscription price $2.00 a year in the United States and possessions. Canada $2.75 a year. Other countries $3.50 a year. Single copies 15 cents.

Copyright 1926, by Technical Publishing Co.

Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the act of March 3, 1879.

Member, Associated Business Papers, Audit Bureau of Circulations

Circulation of this Issue 22,950

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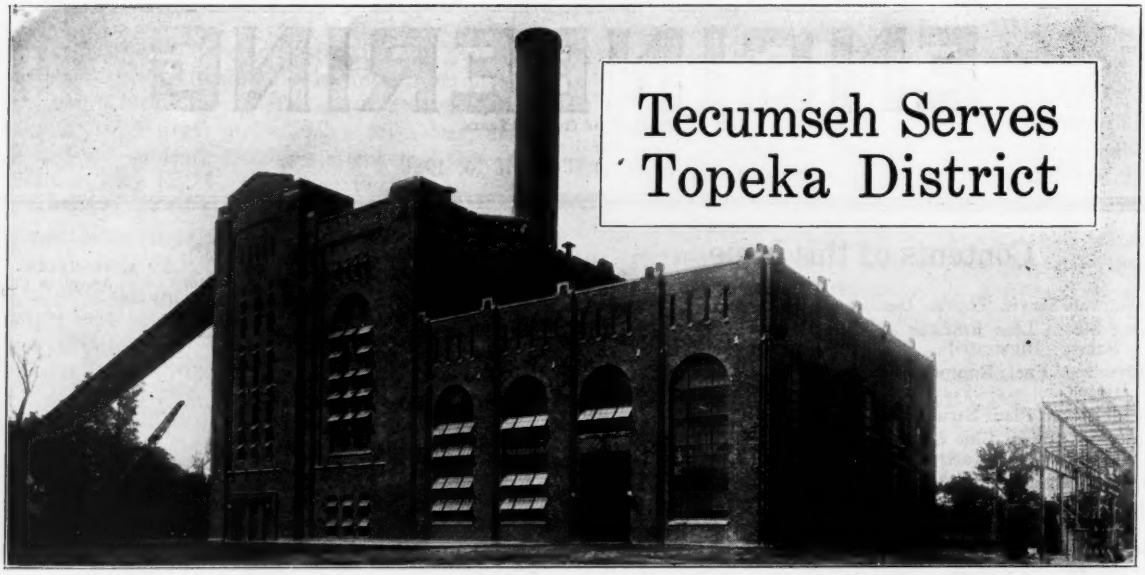
A Pipe Dream

F. W. PEEK, some time ago, when he was playing with extremely high voltages, figured that the conductors of a million-volt transmission line would have to be at least 8 in. in diameter. Of course, at present there is no need for a million-volt transmission line, but we got to thinking and dreaming about it, and first thing you know we had it doing all sorts of things. What would a line like that look like? Imagine an 8 or 10-in. pipe supported on towers stretching out to infinity. Impractical? Not at all. Think of its usefulness for other things than the transmission of electricity. Imagine a line of this type between a power station in one of our cities and the distant coal fields. Pulverized coal could be blown through the transmission line from the mines to the power plant while electricity for running the mines would flow in the opposite direction. Or if it extended from a hydro-electric plant to a city, it could carry the city water supply. All kinds of possibilities.

The picture? No, that has nothing to do with our pipe dream. It did remind us of it, but it refers more specifically to the article on steam lines on page 1095.



Tecumseh Serves Topeka District

NEW PLANT OF KANSAS POWER & LIGHT COMPANY, NEAR TOPEKA, KANS., IS DESIGNED FOR ULTIMATE CAPACITY OF 125,000 KV.A.

TECUMSEH POWER STATION of the Kansas Power and Light Co., a subsidiary of the Illinois Power and Light Corp., was placed in operation in October, 1925. This station is designed for an ultimate capacity of 125,000 kv.a. At present it has an installed capacity of 15,000 kv.a. in two units with room for a third unit of 20,000 kv.a. in the present structure. Steam is generated at 375 lb. pressure, with 250 deg. superheat, a house turbine and motor-driven auxiliaries are used, vertical condensers are installed, an interesting coal and ash handling system is installed and the plant illustrates a type of simple rugged design in keeping with the requirements made upon it.

Tecumseh Power Station is located at Tecumseh, Kansas, on the bank of the Kansas River about 6 mi. east of Topeka, Kansas. It has a railroad connection with the Atchison, Topeka and Santa Fe Railroad, over which Kansas coal is brought to the plant. The plant is operated in conjunction with a steam power plant in Topeka and another in Atchison, Kansas, both of which are Illinois Power & Light Corp. properties. Power is generated at 13,200 v. and is transmitted to Topeka at that voltage. For transmission to Atchison, however, the voltage is stepped up from 13,200 to 66,000. Two 13,200-v. circuits carried on narrow base steel towers run to the city limits of Topeka, where the circuits divide and run on wood poles over separate routes to the Topeka plant. The 66,000-v. line to Atchison is double-circuit on steel towers; from Atchison a single circuit on H-section steel poles extends to St. Joseph, Mo., forming an interconnection with the St. Joseph Railway & Light Co.

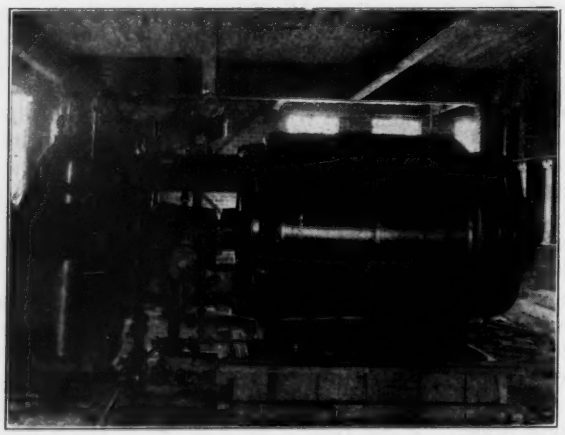


FIG. 1. HOUSE TURBINE SUPPLIES EXHAUST STEAM FOR EVAPORATOR AND FEED WATER HEATER

At present two turbo-generators are installed, as shown in Fig. 2, each with a capacity of 7500 kv.a. In the design of the first section of the station, space was left for a 20,000-kv.a. turbo-generator, which will shortly be installed. The present units are of the 14-stage Curtis type, taking steam at 360 lb. throttle pressure with 250 deg. of superheat. They run at 3600 r.p.m., driving ATB, 6000-kw., 3-phase, 60-cycle, 13,200-v., 0.8 p. f. generators. The steam end is designed for full kv.a. rating at unity power factor. Each unit has a 50-kw., 125-v. exciter mounted on its shaft, as shown. Generator ventilation is by the open system, 21,000 cu. ft. of air a minute being required for each unit. These turbines are furnished with two bleed points, but the regenerative steam cycle will not be employed until the next unit is installed. Main steam lines from the boilers lead to a steam separator installed on the lower boiler room level as in Fig. 4, from which the leads pass up through the turbine room floor, thus keeping the room free of overhead piping.

Each turbine exhausts into a vertical, 2-pass, 16,500 sq. ft. condenser, shown in Figs. 4 and 7E. Circulating water for these is pumped by 15,000-g.p.m. motor-driven centrifugal pumps, three of which are installed, connected to a common header, as shown in Fig. 5, so that varying load conditions and water level fluctuations can be met as required.

Circulating water is obtained from the Kansas River, upstream from the plant and is brought into the plant through a concrete tunnel extending from the screen house on the river. Because of fluctuations in the main channel of the river, a deflection jetty had to be constructed to keep the main flow of the river in the direction of the intake house. To make this jetty, a chain of crossed angle irons was formed, one end of which was anchored on the farther bank of the river opposite the intake house and the other end was dropped into the river on the power house side not far from the intake house. Debris brought down by the river soon began to collect on the chain, which in turn created a sand bar, deflecting the main flow toward the intake.

Vertical condensers were selected for this plant because of the large amount of silt carried by the river as well as the variation of water level, the variation being about 30 ft. At extreme low water, the total combined suction and discharge head on the circulating pumps will be about 30 ft., the usual head being that of condenser and piping friction only. Each condenser is served by a two-stage horizontal single cylinder rotative dry vacuum pump.

Steam for the turbines is supplied by three wrought steel, cross drum water-tube boilers, each containing 12,300 sq. ft. of heating surface. These are equipped with three-pass convection type superheaters of the interdeck type, set as shown. Boilers generate steam at 375 lb. pressure and 250 deg. superheat, the total steam temperature being 685 deg. F. Each boiler is equipped with a single pass economizer of 9120 sq. ft. heating surface mounted above it as shown.

Furnaces Have Side Wall Screens

Boilers are set high, each furnace having a volume of 6600 cu. ft. Each furnace is equipped with a side wall screen with a heating surface of 330 sq. ft., these screens being connected directly to the circulation of the boiler. Side wall water boxes are also installed just above the grate level and are connected to the high pressure circulation system.

Stokers are of the chain grate forced blast type, with a grate surface of 306 sq. ft. each, driven by 7½-hp., 1650-r.p.m. motors. Stokers and settings are designed to burn Kansas coal of approximately 11,520 B.t.u., having a proximate analysis of: Ash, 18.3 per cent; moisture, 5.0 per cent; sulphur, 3.6 per cent. The settings are designed also with oil burning operation in mind, since the plant is not far from the high pressure oil lines which traverse the state of Kansas.

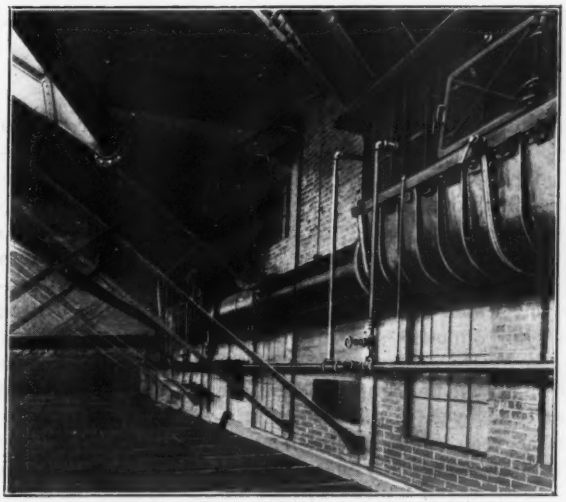


FIG. 3. ASH IS SLUICED FROM THE PLANT IN A COMPLETELY ENCLOSED SYSTEM

Air for combustion is drawn from the top of the boiler room by 60,000-c.f.m., motor-driven, forced draft fans, one for each boiler, installed on the economizer floor, Fig. 4. Here also are located the induced draft fans, one for each boiler, of 96,000 c.f.m. capacity each. The latter draw the flue gas through the economizer and force it through the steel breechings, which are gunite lined and equipped with expansion stiffeners to the steel stacks. One of these stacks, brick lined, is installed to serve the present boilers, but four of them will ultimately be needed. Each stack is 12 ft. 6 in. in

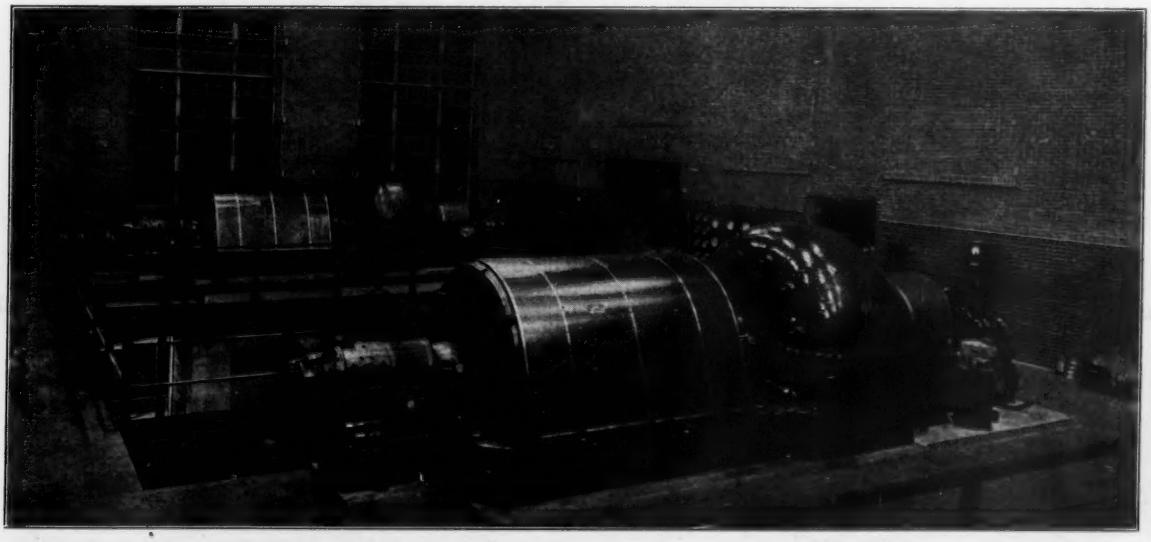


FIG. 2. TWO TURBINES OF 7500 KV.A. CAPACITY EACH ARE INSTALLED IN ATTRACTIVE TURBINE ROOM

diameter and 140 ft. high above the grates. It is supported on the roof structure of the boiler room.

Coal and Ash Handling Equipment

Coal is brought to the plant in railways cars which are weighed on a track scale and from which it is handled to storage by a 25-t. locomotive crane, which can also be used to reclaim it. This crane will also handle ash from the storage pit. Coal that is to go direct to the boiler bunkers is dumped from the railroad cars into a track hopper, from which it loads on an inclined conveyor, which takes it to the coal breaker house located on the opposite side of the track from the boiler house. Here it passes through a 75-t. breaker with 1¼-in. perforations, then goes on another inclined belt conveyor to the distributing conveyor over the boiler coal bunkers, Fig. 7A. Here the belt tripper distributes it at any point in the bunkers. Two spouts open from the bunker to each stoker, feeding a weigh larry that feeds one stoker only. This allows accurate record to be kept of the coal going to each stoker. In addition, the weigh larry travels the full length of each stoker hopper, giving even distribution of coal in the hoppers, an important factor in chain grate stoker operation.

Ash from the stokers drops into hoppers from which it is removed by a hydro-jet ash sluicing system. In this system, ash drops to feed plates in the hopper bottom and is washed from these feed plates by horizontal water jets which force the ash down into the main sluice pipe. Here other water jets carry it along in a closed pipe forcing it through this pipe to an ash storage pit outside the plant, from which it can be removed by the locomotive crane and used for fill or loaded into cars for other disposition. A drippage hopper is provided also at the front of each stoker and is connected with the sluicing system. Figures 3 and 4 show the ash sluicing system as installed.

House Turbine Forms Important Part of Layout

Steam for feed water heating and for evaporators and power for motor-driven auxiliaries is supplied by a house turbine, which has thus an important function in the plant. This unit is installed in the boiler house on the level below the boiler feed pumps and is shown in Figs. 1 and 4. It drives a 750-kw. 0.8 p.f., 60-cycle, 3-phase generator at 3600 r.p.m. furnishing power at 2300 v. It takes steam at 350 lb. gage and 250 deg. superheat, the same as the main turbine. A 10.5-kw., 125-v. exciter is mounted on its shaft. Open ventilation is used for the generator. Reference to Fig. 6, the heat balance diagram of the station, shows the place of the house turbine in the cycle.

River Water is Evaporated for Boilers

Raw water for the plant is taken from the river, passed through a 4000-g.p.h. pressure type sand filter and then goes to the evaporators, installed in the boiler house on the level just below the house turbine. This water can also be sent to a storage tank of 100,000 gal. capacity on a 100-ft. tower, instead of going direct to the evaporator. The evaporator is an Ellipticoil double-effect, horizontal shell, film type unit, with a capacity of 10,000 lb. an hour. It receives part of the exhaust steam at 4 lb. gage from the house turbine. Hot well

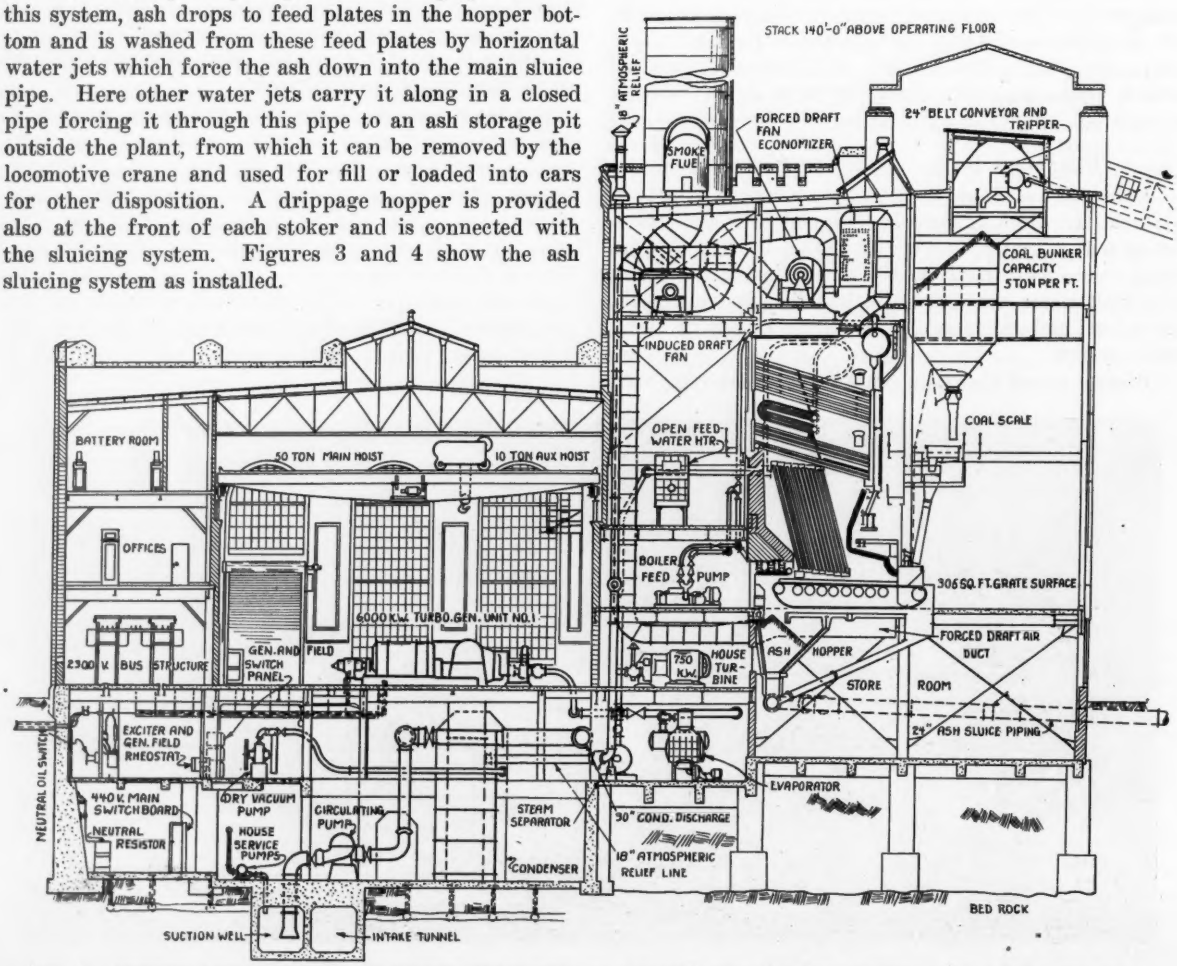


FIG. 4. SECTION THROUGH STATION SHOWS SIMPLICITY OF LAYOUT, VERTICAL CONDENSERS AND HOUSE TURBINE

pumps, which are motor-driven, 270-g.p.m. units, take the main turbine condensate from the hot well, send it to the evaporator condenser, finally to the open feed water heater. Provision is made for addition of make-up water from the storage tank direct to the heater in emergencies.

Two feed water heaters are installed in the boiler room behind the boilers, as in Figs. 4 and 5. These are open, deaerating heaters of 150,000 lb. per hr. capacity each. They utilize about 90 per cent of the exhaust steam from the house turbine to heat the feed water to about 220 deg.

From the heater, the water goes to the boiler feed pumps, Fig. 7B. Three of these are installed, two motor-driven and one steam-turbine-driven for emergencies. Motor-driven pumps are 6-stage, 300 g.p.m. units driven at 1750 r.p.m. by 200-hp. squirrel cage motors, and designed for a head of 1040 ft. The turbine driven unit is 5-stage, 300 g.p.m., against 1040 ft. head, driven by a 160-hp. turbine at 2500 r.p.m. These pumps send the water through the economizers mentioned above to the boilers at about 320 deg. temperature. Feed water level in the boilers is controlled by water level regulators.

Motor-Driven Auxiliaries Predominate

All the auxiliaries in the Tecumseh station, with the exception of one turbine-driven boiler feed pump mentioned above, are driven by a.c. motors. Most of these

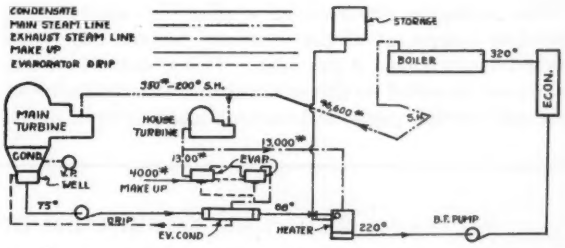


FIG. 6. HEAT CYCLE AT TECUMSEH, THE FIGURES BEING FOR 1¼ LOAD

are wound for 440 v. but some are wound for 2300-v., such as the fire-pump motor. The turbine room crane, which has a 50-t. main hoist and a 10-t. auxiliary hoist, is also driven by a.c. motors.

Besides the pumps noted above, a fire pump, two house service pumps, a sump pump and a makeup pump are installed. The fire pump is a 1000-g.p.m., 462 ft. head, centrifugal, driven by a 200-hp., 2300-v. squirrel cage motor. Each house service pump is a 2-stage, 300-g.p.m., 200-ft. head centrifugal, driven at 1800 r.p.m. by a 440-v. motor. The sump pump is a vertical unit driven at 1800 r.p.m. by a 5-hp., 440-v. motor. The makeup pump, a 75 g.p.m. 85-ft. head centrifugal, is driven by a 440-v., 1800-r.p.m. motor.

Two circulating water screens, 103 in. wide, with ⅜-in. openings are driven at 10 ft. per minute by 1800-r.p.m., 440-v., 5-hp. motors.

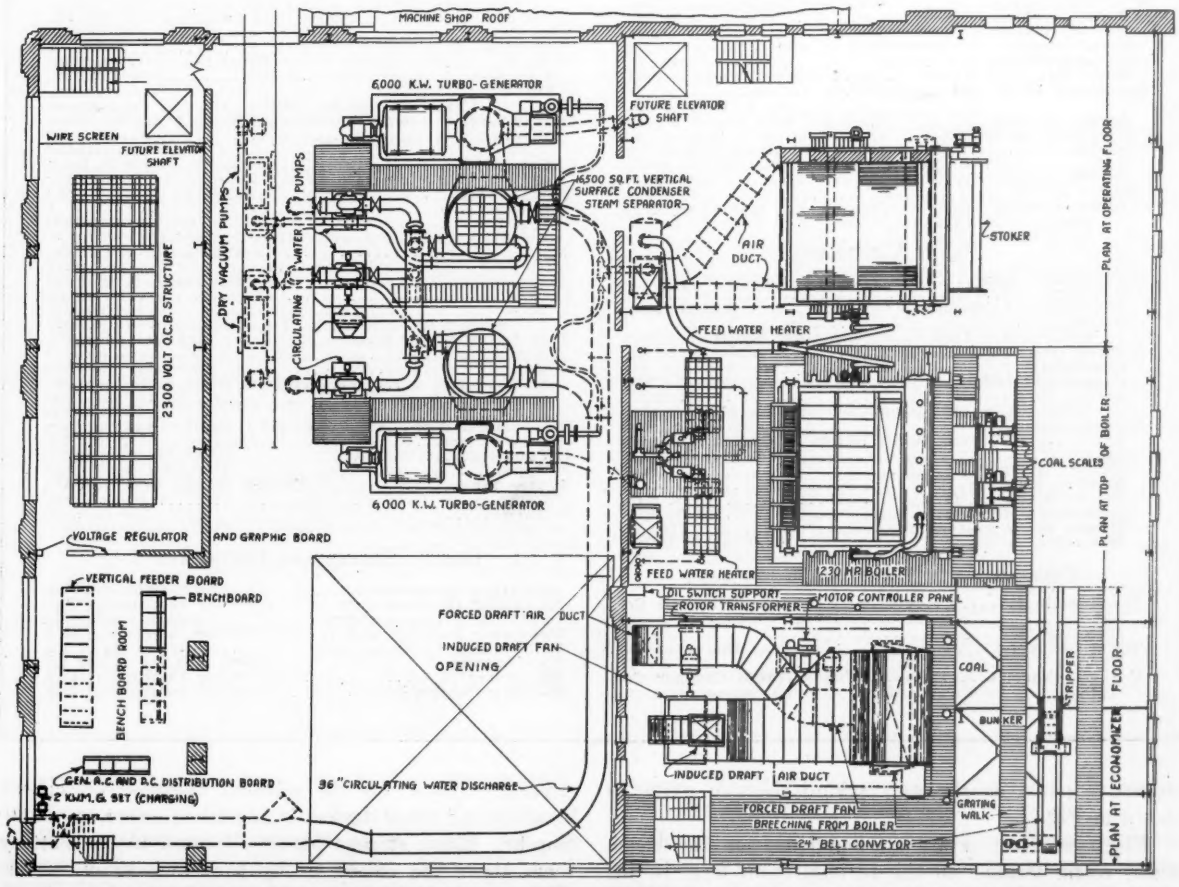


FIG. 5. SPACE IS LEFT IN TURBINE ROOM FOR THIRD GENERATING UNIT AND PLANT SHOWS GOOD ARRANGEMENT OF UNITS

As might be expected in a plant of this type, a complete equipment of the necessary meters, gages and control instruments is provided. Boiler control instruments are installed on suitable boards in the boiler room, and the turbine gages and controls are mounted on an

going circuits at 13,200 v. to Topeka and at 66,000 v. to Atchison, as noted above are handled in the outdoor substation, partly visible at the right in the head piece. In the room just to the right of the bench board room is the 2300-v. bus structure handling the auxiliary

Principal Equipment in Tecumseh Power Station

General

Plant Location—At Tecumseh on the Kansas River, six miles east of Topeka, Kans.
Capacity installed (August, 1926).....15,000 kv.a
Capacity ultimate .....125,000 kv.a.
Railroad connection .....A. T. & S. F. R. R.
Engineers..Illinois Power & Light Corp., Engineering Dept., Chicago.
Consulting architects...Proudfoot, Rawson and Sauers

Boilers, Superheaters and Economizers

Boiler and superheater.....Babcock & Wilcox Co.
Type of boiler..Wrought steel, cross drum, water tube
Number installed 3
Steam making surface per boiler.....12,300 sq. ft.
Tube diameter .....4 in.
Furnace volume .....6600 cu. ft.
Boiler pressure .....375 lb.
Superheat .....250 deg. F.
Total steam temperature .....685 deg.
Type of superheater..Three pass, convection, interdeck
Location of superheater.....interdeck, above 6 rows
Superheater surface per boiler.....2400 sq. ft.
Ratio of superheater surface to steam making surface 195
Economizers.....Power Specialty Corp.
Type of economizer.....Foster, horizontal, one pass.
Number of economizers per boiler.....1
Tube diameter .....2 in.
Heating surface .....9120 sq. ft.
Ratio of economizer to steam making surface..... .74

Furnaces and Stokers

Side Wall Screens.....Combustion Engineering Corp.
Type .....Fin
Number installed .....1 per boiler
Location.....Side walls in combustion chamber
Heating surface per furnace.....330 sq. ft.
Ratio side wall screens to steam making surface .0268
Suspended Front and Bridge Wall Arches.....M. H. Detrick Co.
Length of arch.....45 per cent stoker length
Side wall water boxes.....Babcock & Wilcox Co.
Stokers.....Illinois Stoker Co.
Type.....Forced draft, chain grate
Number installed.....1 per boiler
Grate surface.....306 sq. ft
Drive..General Electric, BTA, 7½-hp., 1650-r.p.m. synchronous speed motor.

Draft Equipment

Forced Draft Fans.....Buffalo Forge Co.
Number.....1 per boiler
Capacity at 4.5 inches W.C.....60,000 c.f.m.
Drive.....G.E., 75 hp., 1200 r.p.m., slip ring, induction motor
Induced Draft Fans.....Buffalo Forge Co.
Number.....1 per boiler
Capacity at 6.38 in. W.C.....96,000 c.f.m.
Drive .....G.E., BTS, 150 hp. 900 r.p.m. synchronous speed motor
Breeching and Flues.....Connery & Co., Inc.
Type.....Steel, gunite lining, expansion stiffeners
Stacks.....Connery & Co., Inc.
Number installed 1
Number ultimate 4
Diameter at base, ft.....12 ft. 6 in.
Diameter at top, ft.....12 ft. 6 in.
Height above grates, ft.....140 ft.
Material.....Steel, brick lining

Coal and Ash Handling Equipment

Track scale .....Fairbanks, Morse & Co.
Type.....100 t., registering beam
Effective rail .....50 ft.
Track hopper.....Stearns Conveyor Co.
Number 1
Coal breaker.....Pennsylvania Crusher Co.
Type.....Bradford, with 1¼ in. perforations
Size .....11 ft. by 12 ft.
Capacity per hr.....75 t.
Locomotive crane.....Brown Hoisting Machinery Co.
Type.....8 wheel locomotive crane, 60 ft. radius boom
Capacity.....21-25 t.
Conveyors .....Stearns Conveyor Co.
Capacity .....75 t. per hr.
Weigh larries.....Richardson Scale Co.
Coal bunkers.....Mississippi Valley Struct. Steel Co.
Ash hoppers.....The Allen-Sherman-Hoff Co.
Number.....1 per boiler
Capacity.....900 cu. ft.
Hydro-jet ash sluice.....The Allen-Sherman-Hoff Co.

Pumps and Heaters

Evaporator.....Wheeler Condenser & Engineering Co.
Type....Double effect, Ellipticoil, horizonal shell, film
Number 1
Capacity.....10,000 lb. per hr.
Heater .....Cochrane Corp.
Type..... Open, deaerating
Number 2
Capacity.....150,000 lb. per hr.
Boiler Feed Pumps.....De Laval Steam Turbine Co.
Number—
Motor driven 2
Steam driven 1
Type—
Motor driven .....6 stage
Steam driven .....5 stage
Capacity—
Motor driven.....300 g.p.m. at 1040 ft. head
Steam driven.....300 g.p.m. at 1040 ft. head
Drive—
Motor driven .....Allis-Chalmers, 200 hp., 1750 r.p.m. Squirrel cage motor
Steam driven.....De Laval turbine 160 hp.
Fire Pump.....Allis-Chalmers Manufacturing Co.
Number 1
Type.....Centrifugal, 462 ft. head
Capacity .....1000 g.p.m.
Drive .....Allis-Chalmers, 200 hp., 2300-v. squirrel cage motor
House Service Pump..Worthington Pump & Machy. Corp.
Number 2
Type.....2 stage, centrifugal
Capacity.....300 g.p.m. at 200 ft. head
Drive..G.E. 30 hp., 1800 r.p.m., 440 v. squirrel cage motor
Sump Pump.....American Well Works
Number 1
Type.....Vertical, centrifugal
Drive.....5 hp. squirrel cage motor, 440 v., 1800 r.p.m.
Make-up Pump.....Fairbanks, Morse & Co.
Number 2
Type..... Centrifugal, 85 ft. head
Capacity .....75 g.p.m.
Drive .....Fairbanks-Morse 5 hp., 1800 r.p.m., 440 v. squirrel cage motors
Circulating Water Screens.....Link-Belt Mfg. Co.
Number 2
Type .....Traveling, elevator
Size.....103 in. wide, ⅜ in. opening
Speed.....10 ft. per min.
Drive ..... Fairbanks-Morse 5 hp., 1800 r.p.m., 440 v. squirrel cage motors
Water Filters.....International Filter Co.
Capacity.....4000 gal. per hr.
Type.....Pressure, sand filter
Water tank.....Chicago Bridge and Iron Co.
Capacity.....100,000 gal.
Tower.....100 ft. high

Gages, Meters and Instruments

Indicating thermometers.....Taylor Instrument Cos.
Recording thermometers.....Taylor Instrument Cos.
Indicating pressure gages.....Ashcroft Mfg. Co.
Recording pressure gages.....Taylor Instrument Cos.
Boiler control instruments.....Bailey Meter Co.
Flow meters.....Bailey Meter Co.
Barometer .....Taylor Instrument Cos.
Mercury Column gage.....Taylor Instrument Cos.

attractive panel on the wall behind the two units, as shown in Fig. 2.

Electrical circuits are all handled from the bench board room, located on the turbine room level in the northwest corner of the room as shown in Fig. 5. Out-

circuits. Power for the solenoid operated oil circuit breakers and other devices is furnished either by a 150-amp-hr., 125-v. storage battery, located in the battery room above the offices, or by a 50-kw., 125-v. motor-generator set, driven direct from the 2300-v. bus.

The 13,200-v. outgoing circuits are handled by the main outdoor oil circuit breakers, of which there are eight. On the 66,000-v. line, the oil circuit breakers have a rupturing capacity of 3520 amp., being designed for 400 amp. at 73,000 v. Power transformers on the six 75-kv.a. 2300/460-v. transformers are installed and lower voltage for the lighting circuits is obtained from two 50-kv.a. 2300/230/115-v. units. Main disconnecting switches are of the air break type, with remote hand control. Switchboards and benchboards are of ebony

Principal Equipment in Tecumseh Power Station—Concluded

Prime Movers

Main Turbo-Generators.....General Electric Co.
Type.....Curtis Horizontal
Number installed.....2
Size (each).....6000 kw., 80 per cent p.f.
Number of stages.....14
Bleeder points.....2 (not in use)
Speed.....3600 r.p.m.
Steam pressure at throttle.....350 lb.
Superheat at throttle.....250 deg. F.
Type of generator....ATB, 3 phase, 60 cycle, 13,200 v.
Ventilation of generator.Open system, 21,000 c.f.m. each
Exciter (direct connected).....50 kw. 125 v.
House Turbine.....General Electric Co.
Type.....Curtis Horizontal
Number installed.....1
Size.....750 kw. 80 per cent p.f.
Speed.....3600 r.p.m.
Steam pressure at throttle.....350 lb.
Superheat at throttle.....250 deg. F.
Type of generator.....ATB 3 phase, 60 cycle, 2300 v.
Ventilation of generator.....Open system, 6000 c.f.m.
Exciter—
Size and type.....10.5 kw., 125 v.
Drive.....Direct connected

Main Unit Auxiliaries

Condensers.....Worthington Pump & Machinery Corp.
Number.....2
Type.....Vertical, cylindrical, 2 pass, surface
Number of tubes.....3950
Outside tube diameter.....1 in.
Cooling surface.....16,500 sq. ft.
Ratio surface to rated kw.....2.75
Circulating Pumps...Worthington Pump & Machy. Corp.
Number.....3
Capacity.....15,000 g.p.m. at 30 ft. head
Drive..G.E. Co. Squirrel cage motors, 200 hp., 695 r.p.m.
Hotwell Pumps.....Worthington Pump & Machy. Corp.
Number.....4
Capacity.....270 g.p.m. at 75 ft. head
Drive...G.E. Co. 25 hp., 1750-r.p.m. Squirrel cage motor
Air Pumps.....Worthington Pump & Machy. Corp.
Number.....2
Type.....Horizontal, single cylinder, 2 stage rotative
Drive.....G.E. Co. 40 hp. Squirrel cage, 900 r.p.m., 440-v. motors

Miscellaneous Mechanical Equipment

Gratings and stairs.....Arrowhead Iron Works Co.
Traveling Crane, turbine room.....Whiting Corp.
Size.....62 ft. span
Capacity.....50 t.
Air compressor.....Sullivan Machinery Corp.
Type.....Class WJ 3
Size.....16 by 9¾ by 10 in.
Drive.....Squirrel cage motor
Soot Blowers.....Diamond Power Specialty Corp.
Copes feed water level regulators.....Northern Equipment Co.
Valves—
Atmospheric relief.....G. M. Davis Regulator Co.
Main steam.....Crane Co.
Circulating water (hydraulic).....The Kennedy Valve Mfg. Co.
Safety.....Consolidated Pop Safety Valve
Blow-off.....Yarway Combination, Yarnall-Waring Co.
Sluice gates.....Rodney Hunt
Boiler stop and check.....Pittsburgh Valve, Foundry & Constr. Co.
Expansion joints—
Rubber.....U. S. Rubber Co.
Copper.....Crane Co.
High Pressure Steam Piping and Fittings.....M. W. Kellogg Co.
Circulating water piping.....Steere Engineering Co.
Pipe Covering.....Johns-Manville, Inc.
Steam traps.....Armstrong Machine Works

Electrical Equipment

Main Oil Circuit Breakers.....General Electric Co.
Type.....FHKo-136, 15,000-v. outdoor
Operation.....Solenoid control 125 v. d.c.
Rupturing capacity.....15,350 amp. at 13,800 v.
Mounting.....Frame mounted outdoors
Number.....8
Auxiliary Power Oil Circuit Breakers.....General Electric Co.
Type.....FK-132 A
Operation.....Solenoid control 125 v., d.c.
Number installed.....18
Motor Generator Sets.....General Electric Co.
Number installed.....1
Generator.....50 kw. compound wound 125 v. d.c.
Motor.....75 hp., 2200 v., 3 phase, 60 cycle, 1200 r.p.m.
Control Storage Batteries...Electric Storage Battery Co.
Type.....F-9, 11 by 10½ in. plate
Capacity.....150 amp. for 1 hr.
Number of cells.....60
Voltage.....125
Transformers—
Main station power.....3 333-kv.a. Moloney Electric Co., 13,200-2300 v.
440 volt power.....6 75-kv.a. General Electric Co., 2300-460 v.
Station lighting.....2 50-kv.a. General Electric Co., 2300-230/115 v.
Main Disconnecting Switches.....Railway & Industrial Engr. Co.
General.....Outdoor 15,000 v. and 73,000 v.
Operation.....Remote hand control
Type.....Air Break
Number installed.....72 15,000v., 30 73,000-v.
Main Current Transformers.....Westinghouse Elec. & Mfg. Co.
Type.....OA outdoor type
Main potential Transformers.....Westinghouse Elec. & Mfg. Co.
Main Generator Control Benchboard.....Westinghouse Elec. & Mfg. Co.
Material.....Ebony asbestos
Main Feeder Control Switchboard.....Westinghouse Elec. & Mfg. Co.
Type.....Vertical
Material.....Ebony asbestos
House Service Switchboard.....Westinghouse Elec. & Mfg. Co.
Type.....Vertical
Material.....Ebony asbestos
Neutral Grounding Equipment.....General Electric Co.
Oil switches...FK-132 B single pole, solenoid operated
Grounding resistance.....General Electric 8 ohm, 1000 amp., 7900 v. for 30 second duty 450 deg. C. rise
Outdoor Substation Structure.....Railway & Industrial Eng. Co.
Power Transformers.....General Electric Co.
Number.....6
Size and type.....2000 kv.a. O.I.S.C. 66,000-13,800 v.
Oil Circuit Breakers.....General Electric Co.
Number.....5
Rating.....73,000 v., 400 amp. solenoid operated
Type.....FHKO-136-73,000 v. outdoor
Rupturing capacity.....3520 amp. at 66,000 v.
Lightning Arresters.....General Electric Co.
Type.....Oxide film
Number and voltage.....2 73,000-v., 4 15,000-v.
Outdoor Disconnecting Switches.....Railway & Industrial Eng. Co.
Type.....Air break, remote hand operated
Choke Coils.....Railway & Industrial Eng. Co.
Cable—
Outdoor.....17,000 v. varnished cambric, lead covered
Indoor.....17,000 v. varnished cambric, braided
Carrier Current Telephone Equipment.....General Electric Co.

66,000-v. line consist of six 2000-kv.a. 66,000/13,800 v. units.

Main station power can also be obtained from the generator leads through a bank of three 333 kv.a. 13,200/2300 v. transformers. For the motor circuits, asbestos. Complete equipment is installed for carrier current telephone communication.

The power plant building is of reinforced concrete, steel and brick, as shown in the illustrations. It presents an exceedingly pleasing appearance architectu-

rally, the building lines having been well handled to avoid the "cracker-box" effect. The turbine room walls are of brick with a wainscoting of glazed tile. This room is spacious and well lighted and was designed with future expansion in mind. The benchboard room will be near the center line of the turbine room in the completed 125,000-kw. plant.

At present, the south wall of the boiler room is of temporary construction, since if any additional boilers are installed, they will be placed in an extension opposite the three present ones, with the firing aisle between.

Of particular interest at Tecumseh is the roof construction. The roof over the boiler is a concrete slab, poured in plate, reinforced with triangular steel mesh and covered with a composition roof. The roof over the turbine room consists of steel lathing into which was pressed, from the top side, a comparatively dry mix of concrete. Over this was spread a sand cushion and on that a course of gypsum insulating blocks, the whole covered with composition roof covering. This roof was used for the turbine room to reduce vapor condensation and prevent dripping on the equipment below.

Engineering design and construction of the plant was done by the engineering department of the Illinois Power & Light Corp., Chicago, Ill., in charge of T. J. Lucas, chief engineer. Field work was handled by C. A. Leland, resident engineer. J. W. Sykes and W. G. Copeland directed the mechanical and electrical work from the Chicago office.

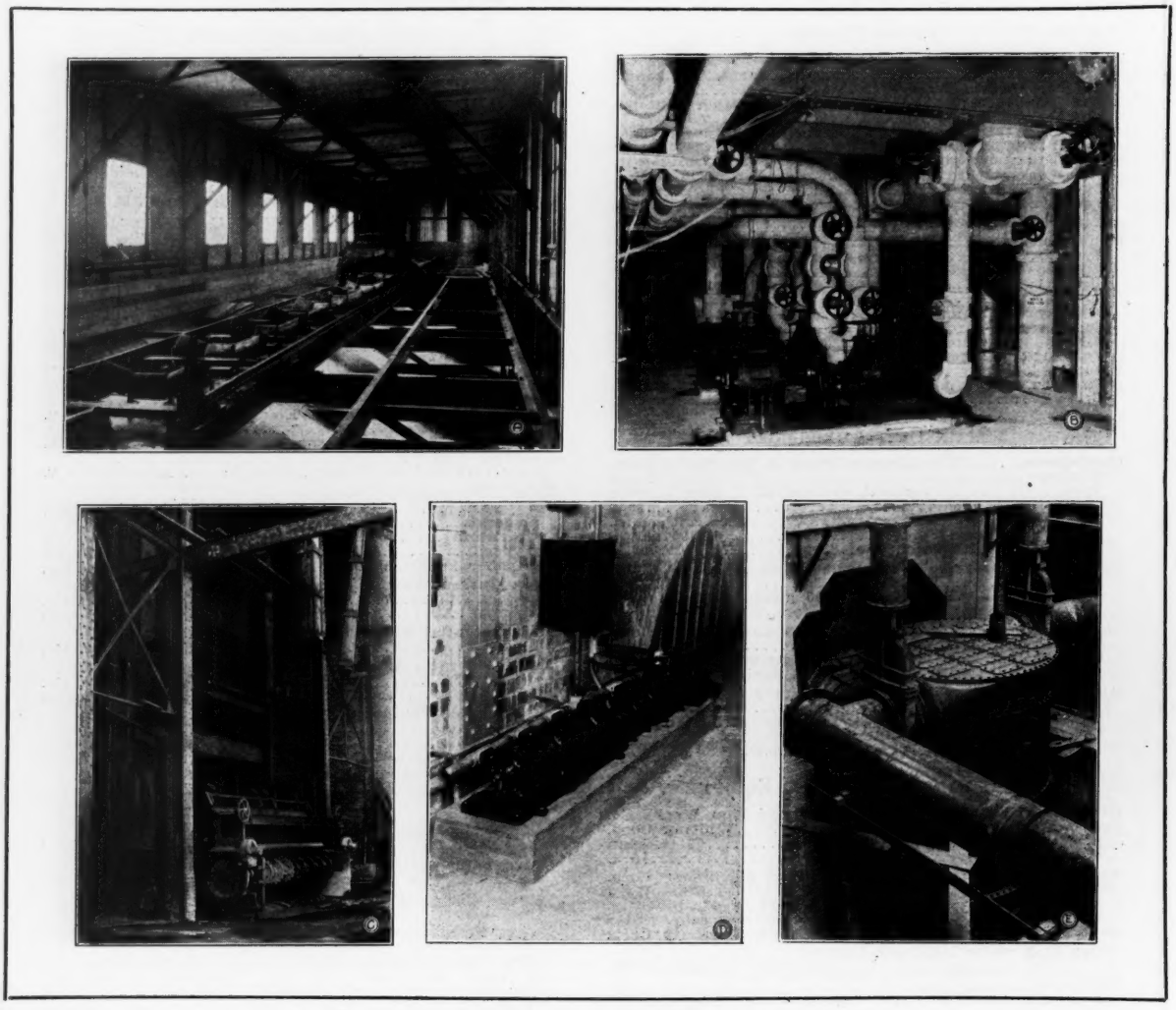


FIG. 7. DETAILS OF PRINCIPAL EQUIPMENT AND AUXILIARIES

A—Conveyor over boiler bunkers with tripper, belt removed. B—Two boiler feed pumps are motor-driven and one is turbine-driven. C—One of the boilers and its chain grate stoker under erection. D—Motor-generators for the carrier current telephone system. E—Vertical condenser under erection; circulating water lines are controlled by hydraulic operated valves. Vertical condensers used because of silt in river water and variation of river level.

COMPRESSORS are rated by the manufacturers in terms of piston displacement in cubic feet per minute. This should not be taken as the capacity or actual air delivery of the machine, which will be somewhat less depending upon the volumetric efficiency.

INATTENTION has cost many a worker a finger, a toe, a leg, an arm, a life, laments the National Safety Council.

Long Steam Line Efficient at High Pressure

STEAM EQUIVALENT TO 10,000 KW. DELIVERED AT 163 LB. THROUGH 4500-FT. LINE WITH 3 PER CENT LOSS. BY R. H. BAKER

SINCE MAY, 1925, a steam line nearly a mile in length has been in operation at East Walpole, Mass., carrying 30,000 lb. of steam an hour at 165 lb. for 24 hr. a day and with an efficiency which has resulted in a saving over developing the steam at the delivery end of the line. It was designed and installed by the R. H. Baker Co., of Cambridge, Mass., from designs which were checked and approved by John A. Stevens of Lowell, and carries the steam from the East Walpole plant of Bird & Son, Inc., to that company's Norwood plant.

This line was designed to transmit steam ultimately at a pressure of approximately 200 lb. with 100 deg. superheat an exact distance of 4550 ft., but at present, initial pressure is about 165 lb. and there is no superheat. The conditions affecting the decision to install this line were as follows: Steam was originally generated at both plants and used locally; the cost of steam generated at the East Walpole plant was approximately one-half of that at the roofing plant, due to the fact

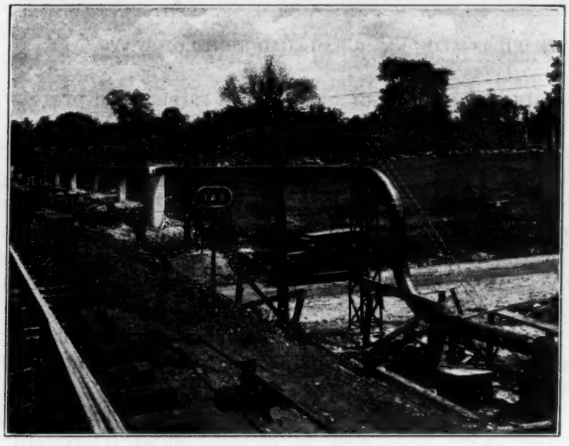


FIG. 1. 8-IN. LINE CROSSES WATER ST. OVERHEAD

that the latter plant was much smaller and the operating cost correspondingly higher. In determining the feasibility of this installation, the fixed charges on the old plant, which would necessarily be shut down, were charged against the steam line, amounting to approximately 20c per 1000 lb. of steam. In spite of these additional charges carried by the steam line, it was estimated that a material saving could be effected by its installation and this has been fully borne out during the past year, the net saving having been approximately 15c per 1000 lb. of steam.

Water used for the generation of steam is taken from the Neponset River and, after having been softened, is fed to the boilers. The steam generated is then transmitted by this line to the Norwood plant, where it is used in process work. Although the feasibility of returning condensate to the boiler plant is being considered, at the present time it is wasted to the river.

The line consists of 8-in. steel pipe of 0.322 in. thickness. Because of the fact that this pipe line was constructed on the railroad right of way, it was necessary to keep the center of line of the pipe at least 8 ft. from the center line of the railroad tracks, which left too little room to use expansion U-bends; it was necessary, therefore, to use slip joints in almost all cases. Crosshead guided expansion joints, Fig. 4, were selected with bodies of cast-steel and slip tube of steel, copper plated, having maximum traverse of 8 in. They were located every 140 ft. or as near that as possible. The base of each joint was securely anchored in a solid concrete reinforced pier, so that expansion of the line starts, in

FIG. 2. RAILROAD TRACKS ARE CROSSED 30 FT. ABOVE GROUND

each case, at the anchored solid flange on the body of the joint and travels in the direction of flow into the next joint. At all changes of direction, anchors were located ahead of, i. e., on the inlet end of the turn and expansion is in the direction of steam flow, which causes maximum travel of the pipe to occur on straight lines only and eliminated the necessity for alinement guides on the main line. At expansion U-bends, anchors were placed beyond the bend and alinement guides before the bend, Fig. 3, the crowns of the bends being left free to move at right angles to the line.

At Norwood plant, the line crosses the railroad, Fig. 2, and travels approximately 300 ft. on steel towers 30 ft. above ground. As slip joints were undesirable in this location, the expansion of this 300-ft. run was taken up with one large expansion U-bend, 30 ft. center to crown. This bend was purposely made much larger than necessary, so as to reduce the thrust on its anchorage, which was located on the Norwood boiler house roof.

The line is supported on reinforced concrete piers, Figs. 1 and 2, 20 ft. on centers, with which spacing there is no detectable deflection in the piping. In fact, as 40-ft. lengths of pipe were used where possible, it

FIG. 3. LINE IS CARRIED ON REINFORCED CONCRETE PIERS ALONG THE RAILROAD RIGHT OF WAY

was found in placing this pipe that, even when supported 35 ft. or more on centers, no deflection could be detected.

Joints Are Welded

All joints in the piping, except at expansion joints and U-bends were butt welded, V-type, electrically, slightly reinforced by crowning over the weld, Fig. 5. Welds were then air-hammered and annealed, the annealing being accomplished by use of twin kerosene burners with a specially constructed portable furnace. The strength of this type of joint was well demonstrated during construction of that portion of the line which runs 30 ft. above the ground. A 40-ft. length and a 20-ft. length were welded together to be hoisted in position. In hoisting, the sling slipped, causing the load to be balanced at one point, with an overhang of 30 ft. of pipe on each side. No deflection could be found and no damage was detectable in the weld. The pipe line was tested with a minimum hydrostatic pressure of 500 lb. per sq. in., with no leaks in any weld.

The line was insulated with 85 per cent magnesia, two layers 1½ in. thick, with joints staggered in alternate layers, a total of 3 in., and covered with two layers of Bird & Son Paroid roofing.

Operation is Safeguarded

In case of rupture, the line is protected by a triple-duty valve at the inlet end, while a non-return valve is provided at the discharge end to prevent the back flow of steam in the event of the Norwood boiler plant being placed in operation. The line is dripped at eight points between inlet and outlet, each drip being equipped with two traps.

In pipe lines of this length, great care must be used in warming up, because of possibility of water hammer and unequal expansion strains. Attention must be given to gradual increase of temperature rather than pressure. To check the operation of warming up carefully, a recording thermometer, with bulb located approximately 200 ft. from the inlet valve, is used, the dial being located at the inlet valve. About 2 hr. are required to warm up the line when cold. Care is also exercised in shutting down, not because of water hammer but for the reason that sudden contraction puts undue strain on anchorages, alinement guides and joints.

An externally-controlled, double-beat valve is used at the discharge end of the line, reducing pressure from approximately 140 lb. gage to 110 lb.

Maintenance is limited to the repacking of slip joints about every 2 yr. and, in recognition of its stability, the Hartford Steam Boiler Insurance Co. has accepted this line and insured it for $100,000.

Tests Show Good Efficiency

On February 11, 1926, this line was tested in order to determine its actual operating efficiency, with results as follows:

This test was of 8 hr. duration, starting at 8:30 a. m. and ending at 4:30 p. m., the average outdoor temperature being 25 deg F. Actual length of the line is 4550 ft. but, including the pipe length for resistance offered by bends, valves and fittings, the equivalent length is 4839 ft. At the inlet, the average pressure was found to be 163.3 lb., and the quality of steam 99.154 per cent dry, or having 0.846 per cent moisture. At the end of the line, the pressure was 133 lb. and the quality of steam 96.52 per cent dry with 3.48 per cent moisture. Steam flowing per hr. was 31,204 lb. and pressure drop throughout the length of the line 30 lb. Condensate was weighed and totaled for the test 1328 lb., or 166 lb. an hour. Heat loss in the latent heat of steam condensed was 791,779 B.t.u. an hr., and that carried away by the

condensation which was trapped off was 195,345 B.t.u., or a total of 987,124 B.t.u. an hr. Total heat sent out from East Walpole was 36,720,243 B.t.u. and that received at Norwood 35,733,119 B.t.u. an hr., the difference being that due to the loss as given above. Dividing the heat lost in the line by that sent out from East Walpole gives 2.688 per cent as the line loss.

This test was made by J. A. Sheehan, assistant engineer for Bird & Son, Inc., and in making the test high grade thermometers were used, also calorimeters of design approved by the A.S.M.E. In making calculations, Goodenough's steam tables were used, and Kent's formula for determining the quality of steam, the low point for the steam being figured as the temperature of make-up water which, on the date of the test, was 45 deg. F.

As will be observed, the actual heat loss is less than 3 per cent, an amount which compares favorably with the transmission line loss of an equivalent amount of electrical energy. This condition is due to the fact that the line has a 24-hr. load so that, at no time during the day, does the flow cease. Further proof that the heat losses are small is the fact that during the winter, snow lies for a long time on the line. Pressure drop is about 18 per cent although this is of no practical importance due to the fact that all the steam is used for process work.

Actual energy transmitted in 30,000 lb. of steam an hr. is equivalent to an approximate electrical load of 10,000 kilowatts, based on B.t.u. equivalent of electrical energy.

Pipe Line Size Accurately Figured

It is interesting to note how closely the performance of this line checks with Ledoux's formula as given in Annales Des Mines for 1892. For the diameter of a long steam line this formula is as follows:

$$D = 0.699 \sqrt[5]{\frac{W^2 L}{P_1^{1.94} - P_2^{1.94}}}$$

where D = Internal diameter of pipe in inches
W = Steam flow in pounds a minute
P_1 = Pounds per square inch absolute pressure at inlet
P_2 = Pounds per square inch absolute pressure at outlet
L = Length of line in feet

Solving for theoretical discharge pressure, using the equivalent length of line as given, we find

W = 31204 ÷ 60 = 520 lb. of steam a minute
P_1 = 163.3 + 14.7 = 178 lb. absolute.
P_2 = 133 + 14.7 = 147.7 lb. absolute
L = 4839 ft. (including all bends, fittings, valves, etc.)

$$D = 0.699 \sqrt[5]{\frac{520 \times 520 \times 4839}{178^{1.94} - 147.7^{1.94}}} = 8.03 \text{ in.}$$

Inasmuch as the actual diameter of this line is 7.981 in., the error through the use of this formula is only 0.6 of one per cent. From this it would seem that the determination of pipe sizes for long lines from Ledoux's formula is sufficiently accurate for all practical purposes.

From the preceding discussion, it may be concluded that, under certain conditions, it is economical to concentrate the generation of steam at one point and distribute through steam lines to more distant points.

Principal Equipment and Materials Used in Construction

Pipe—National Tube Co.

High-pressure steam fabricated pipes and bends—Walworth Co.

Cast-steel fittings—The Kelly & Jones Co.

Expansion joints—Ross Heater & Mfg. Co., Inc.

Cast-steel, monel-mounted gate and globe valves—The Lunkenheimer Co.

Triple-duty valve—Lagonda Mfg. Co.

Stop and check valves and bronze valves—The Lunkenheimer Co.

Pressure-reducing valve—Ruggles-Klingemann Mfg. Co.

Safety valves and steam gages—The Ashton Valve Co.

Steam traps—The C. E. Squires Co.

Flow meters—General Electric Co.

Recording thermometers—The Foxboro Co., Inc.

Structural steel towers—Boston Structural Steel Co.

Magnesia pipe covering—Keasbey & Mattison.

Pipe-covering jackets—Bird & Son., Inc., Paroid roofing.

Contractor for entire installation—R. H. Baker Co., Inc.

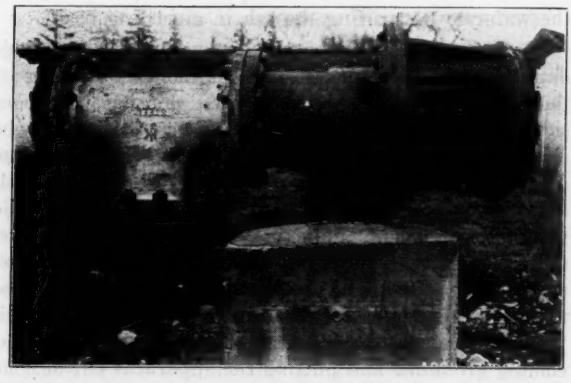


FIG. 4. ANCHORS ARE PLACED AT EXPANSION JOINTS AND CONDENSATION TRAPPED FROM DRIP TEES

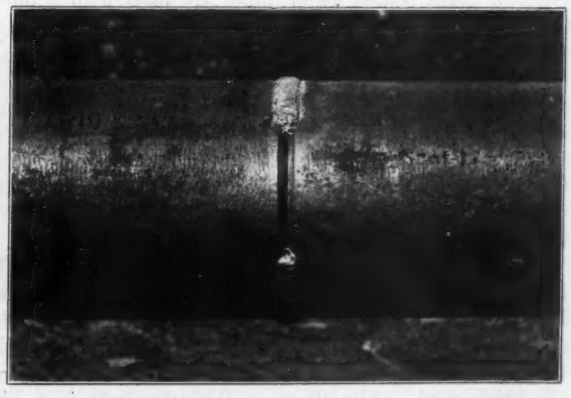


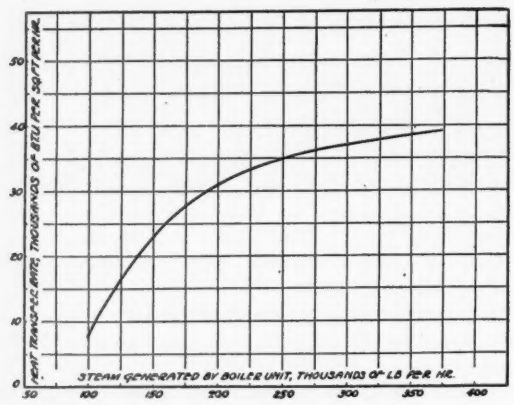
FIG. 5. LINE JOINTS ARE BUTT WELDED. THE TOP PART HAS BEEN AIR-HAMMERED

Pulverized Fuel Equipment Shows Steady Gain

WATER-COOLED FURNACE WALLS, INCREASED POPULARITY OF THE UNIT SYSTEM, NEW DRYERS AND DRYING METHODS, HYDRAULIC ASH SLUICES AND DEVELOPMENT OF TURBULENT BURNERS ARE OUTSTANDING FEATURES OF YEAR'S PROGRESS*

CONTINUED INCREASE in the number of stations adopting pulverized fuel firing has been reported during the past year, while extensions in the generating capacities of several of the larger plants already using pulverized fuel has resulted in a further increase in the total pulverized-fuel steam-generating equipment installed or contemplated.

Perhaps the most decided trend during the year has been in the direction of water-cooled walls and the elimination of refractories. One installation now under construction will have a furnace practically without refractories, the effective heating area of the furnace walls and floor screen amounting to approximately 10 per



TESTS SHOW HIGH HEAT TRANSFER RATE FOR WATER SCREENS AT TRENTON CHANNEL

cent of the boiler heating surface. This additional area is added to the boiler surface to determine the nominal rating of the unit.

Water screen heating surface may be used as part of the main circulating system of the boiler or as a separate steam generating unit. With the latter, saturated steam may be delivered to the boiler drum and passed through the regular superheater, or, through a separate superheater direct to the steam main. In the Fordson plant finned water tubes are used with a portion of the fins cut away for the installation of a radiant heat superheater in the intervening space. Heat transfer tests of a screen boiler at Trenton Channel are shown graphically by the curve. This boiler has a steam making surface of 29,087 sq. ft. with a 6070-sq. ft. superheater and an 18,850-sq. ft. economizer. Saturated steam from the 1220 sq. ft. of water screen is delivered direct to the boiler drum at a pressure of from 405 to 415 lb. per sq. in.

Little difficulty appears to be encountered with properly installed water screens and good water. The Duquesne Light Co. has found several changes advisable and reports, "As originally installed, the rear tubes and those on one side wall were set several inches out from the brick work, while those on the other side were set against the brick work. It was found that the tubes set out from the wall cooled the gas, resulting in incomplete combustion and smoke, and these tubes were later set back against the wall. The front wall of this boiler was constructed with horizontal air ducts for admitting secondary air to the furnace. This did not seem well adapted to give proper distribution of air, and on the second furnace constructed vertical ducts were used, admitting the air at both the bottom and top of the ducts.

The first two furnaces at Colfax were built with air-cooled side walls, using the water screen on the bottom and rear walls. The air-cooled side walls eroded very rapidly; and large pieces of ash and slag collected thereon, resulting in difficult furnace operation and making it necessary to lower the furnace temperature by increasing the excess air. When the last three boilers were constructed at Colfax, fin tubes were used on the side walls and plain tubes on the bottom and rear walls. After these boilers had been operated for some time, the improvement over the air-cooled wall was so marked that fin tubes were placed on the inside of the air-cooled walls in the first two furnaces, and at the same time the plain tubes on the rear wall were changed to fin tubes, extending them higher up so that the entire rear walls to the bottom of the boiler tubes are protected.

FRONT WALLS WILL PROBABLY BE WATER-COOLED IN FUTURE

"There still are plain refractory front walls in all furnaces and some erosion has taken place, particularly where the air ports are not directly back of the burner. Undoubtedly on the next furnaces constructed the front walls will be water-cooled.

Slag on the front boiler tubes has caused trouble in some places, and, when dislodged with hand lances, causes difficulties in the ash handling if steam jet conveyors are used. Fortunately this is a minor point, as some form of hydraulic sluice appears to be the most satisfactory method of ash disposal, unless the ash can be dumped directly into cars from the ashpit. One plant reclaims the water by separating the ash in a settling basin.

Dust from the cyclone and bin vents is being eliminated by piping them either to the boiler breeching or the base of the stack. In the past this has been considerable trouble and one that could not effectively be eliminated by secondary cyclone or water sprays. Flue dust collection by cindervane fans and wetted scroll cases have been applied with apparent success while recent developments indicate that it is possible to remove 95 per cent or more of this ash by electrical precipitation. Although preliminary tests demonstrated that a large percentage of ash could be removed this way, trouble was experienced in wires burning off, becoming grounded and putting the apparatus out of commission. Experiments were carried on with glass tubes and later with vertical instead of horizontal wires and

*Abstract of N. E. L. A. Prime Mover's Committee Report on Pulverized Fuel.

concrete instead of corrugated sheet iron plates. The results with the latter type were satisfactory and present good possibilities.

Exhaust Fan Blades Require Constant Replacement

Powdered coal is more difficult to hold than oil and dust from conveyors and exhausters is a matter of constant watchfulness. Where possible all parts are kept under a slight suction with vents and bleeders taken to the boiler breeching. Wear on transport piping conveyors and especially fan blades is considerable. Rather extensive tests with different materials were made by the Detroit Edison Co. with the results given in Table I. Feeder screws wear rapidly, although they may be built up satisfactorily by means of electric arc welding.

Furnace volumes range between 3.5 and 10 cu. ft. per rated boiler horsepower, with a tendency in the newer installations toward the lower rather than the upper limit. This is being brought about by water-cooling of furnace walls and means for increasing the turbulence of the coal and air mixture as it is injected into the furnace. Furnaces constructed with refractory-

TABLE I. EXHAUST FAN BLADES WEAR RAPIDLY REGARDLESS OF THE MATERIAL FROM WHICH THEY ARE MADE

Material	Number of Sets	Average Hours in Service
Boiler plate, 5/16 in. thick	30	1,463
Boiler plate, glass plated	2	1,026
Steel, copper plated	1	970
Manganese steel	1	612
Brass	1	370
Micarta	1	176
Rubber, vulcanized on plate and riveted along edge	1	54
Rubber, vulcanized on plate	1	4
Rubber, glove shape	1	1

covered water tubes show good performance in the elimination of smoke at low ratings and the capacity for burning large quantities of coal per cu. ft. of furnace volume when forced. Several types of burners for increasing the turbulence of the air-coal jet have been developed. Combustion rates with regard to furnace volumes are given in Table II. As a rule, the minimum rating is limited by overheating due to insufficient air supply through the upper secondary air openings at low loads, while the maximum rating is determined by the capacity of the fuel feeders or fans.

Eliminating Moisture in Mill System

Several methods of drying coal are employed by different companies. In some instances where no driers are used, some drying of the coal is effected by admitting warm, dry air to the mill circulating system and bleeding off a corresponding quantity of air, which carries off the moisture. In one case, where the moisture given up by the coal in pulverizing later collected on the cyclones and piping, the trouble was corrected by using the preheated primary air for combustion through the mill system. The efficiency loss due to the water vapor carried into the furnace is easily made up by less interruption and better flame regulation in the furnace.

Bridging of coal in the bunkers causes no serious difficulties and may be corrected by changing the slope of the bunkers. Agitators above the feeders, steel bunker and pounding the walls of the bunkers are also effective remedies. With dry coal no trouble is experienced but, as the moisture increased, bridging is likely to occur. One company reports conveyor and transport difficulties with 2 per cent moisture while another apparently handles 20 to 22 per cent moisture with no more serious trouble than bridging in the bunkers.

In practically all cases where reliable information could be obtained, it was found that the coal being used was that which could be delivered to the plant for the lowest cost per B.t.u. rather than the lowest cost per ton. Wherever two coals have about the same cost per

TABLE II. TABULATION OF COMBUSTION DATA SHOWS WIDE VARIATION IN OPERATING CONDITIONS

Plant	Furnace Volume, Cu. Ft. per Sq. Ft. of Heating Surface	Rate of Combustion					
		Minimum		Average		Maximum	
		Boiler Rating %	B.t.u. Liberated per Cu. Ft. per Hr.	Boiler Rating %	B.t.u. Liberated per Cu. Ft. per Hr.	Boiler Rating %	B.t.u. Liberated per Cu.Ft. per Hr.
Parr Shoals	0.71	150	8,830	225	13,000	325	19,200
Susquehanna River	0.75	150	8,350	225	12,300	325	18,100
Lake Shore	0.85	135	6,200	167	8,000	300	15,000
Trenton Channel	0.83	175	8,700	210	10,470	380	19,300
Colfax (a)	0.58	140	9,700	235	16,600	325	23,800
Colfax (b)	0.57	140	9,700	215	15,000	250	17,700
Brunot Island (c)	0.44	140	12,800	165	15,500	260	25,600
Brunot Island (d)	0.51	100	8,000	180	15,000	260	22,600
Cecil (e)	0.60	20	1,700	...	.....	330	22,800
Cecil (f)	0.63	20	1,600	...	.....	330	21,700
East Peoria	1.00	...	.....	...	9,500	...	18,000
Lakeside	0.68	50	2,880	225	13,000	300	17,300
South Street	0.35	115	14,000	200	23,500	228	27,000
Mahoningside	0.51	...	.....	185	17,130	275	28,450
Toronto	0.62	...	9,050	...	17,600	...	24,800
Valmont	0.76	35	2,210	200	15,470	250	18,200
Station No. 3 (g)	0.48	50	5,000	145	15,200	225	22,500
Station No. 3 (h)	0.69	75	5,300	155	11,000	270	19,000
Big Sioux	0.76	140	8,000	170	9,800	360	20,700
Island	0.71	...	1,690	...	.....	...	25,400
Cahokia (i)	0.64	120	7,900	180	11,070	200	12,450
Cahokia (j)	0.69	120	7,390	185	10,580	220	12,890
Cahokia (k)	0.69	120	7,390	200	11,440	240	14,230
Cahokia (l)	0.69	120	7,390	200	11,440	300	18,230
Ashley Street	0.57	125	8,900	250	17,800	330	23,490
Manchester Street	0.76	100	5,800	200	11,000	300	17,600
Springdale	0.81	...	.....	285	15,100	350	24,000

B.t.u., other things being equal, the one having the higher heating value is usually selected because of the smaller quantity to be handled, with a resulting lower cost of operation and maintenance of preparation and burning equipment.

Anthracite Can Be Burned But Preparation Costs Are Higher

At the Binghamton and Susquehanna River stations, anthracite fines have been burned with success. Boiler ratings and efficiencies, however, are not as high as can be obtained with bituminous coal. Bituminous coal costs less to pulverize, one mill which was used for both kinds of coal during the year averaged 8.1 kw-hr. per ton on bituminous coal and 23.3 kw-hr. per ton on anthracite coal. The output of this mill averaged 8.7 t. per hr. on bituminous coal as compared with 3.6 t. per hr. on anthracite. Anthracite is used chiefly as an emergency fuel, as it may be stored in enormous piles without danger of deterioration. The United Electric Railways Co. at Providence, R. I., has tried Rhode Island anthracite, but because of its low volatile content, it was found impossible to burn this coal alone. When mixed with 25 per cent New River coal it burned with good efficiency.

Explosions have been few and none serious. One cyclone explosion was caused by sparks from an acetylene welding torch entering the mill system during repair work while another was caused by soot blowers being operated while the boiler was down. The fine dust blown against the hot walls exploded, blowing open the doors.

Air Preheated Above Temperature of Exit Flue Gas

Air preheating of both secondary and primary air is general, the latter usually being tempered with cold air to a temperature of 175 to 200 deg. Higher temperatures tend to volatilize the coal on the feeder and impede a steady flow to the burner. Secondary air ranges from this temperature to 536 deg., depending upon the heaters and equipment arrangement.

At the Sherman Creek station six similar boilers are equipped with different type burners. One of these, No. 10, is equipped with a well type furnace. Originally combustion took place almost entirely within a small water-cooled burner box. Difficulties encountered in keeping the boxes tight, however, led to the present arrangement of a simple burner pipe installation to set up a violent turbulence in the entire furnace.

In commenting on their tests at this station, the United Electric Light & Power Co. say, "The earlier tests conducted indicated that the efficiency with the bin and feeder system was about 5 to 10 per cent higher at high ratings with the unit systems. After much experience with the apparatus, however, it was found that practically equal results could be obtained by either system as long as the furnace conditions were similar.

Flue Gas Analysis of Little Value Unless Flue Dust Is Considered

"The differences in performance between the burners in which a small part of the air was injected with the coal and those of the mixing type in which all of the air for combustion was mixed with the coal before injecting into the furnace, were comparatively slight and apparently furnace conditions were more important, as far as efficiency was concerned, than the details of burner arrangements.

"The appearance of the flame in the furnace was found to be very deceiving. It was soon learned that the flue gas analysis was of little value without the analysis of the flue dust leaving the boiler, and in many instances the latter was far more important than the flue gas analysis as far as the heat balance was concerned. With practically every boiler test there was slagging at some time or other, but by proper means it was either eliminated or controlled. The furnaces in which the greatest turbulence was produced were those in which the heat supplied by the coal per cubic foot of furnace volume was greatest. This seemed to indicate that the size of the combustion space could be reduced, provided sufficient turbulence could be maintained in the furnace. At the same time, the slagging tendencies are increased by the same conditions which produce high efficiencies, turbulence and high furnace temperatures."

There is still a predominance of central preparation systems for large installations but the unit system is being given serious consideration for new installations. In many cases where old boiler plants have been rebuilt the unit system has been found to be the more economical solution.

Need Power Plant Structures Be Unattractive?

WE HAVE BEEN extremely gratified by the manner in which the article, "Need Power Plant Structures be Unattractive?" published in our July 15 issue, has been received. It has been favorably commented upon everywhere and our plan for more attractive structures heartily seconded.

Below we publish an editorial from the Schenectady, N. Y., Star which further stresses the value of attractiveness in power plant structures.

"The commercial value of well appearing buildings and surroundings is reflected in the publication in Power Plant Engineering, a Chicago technical journal, of this appreciation of the unique steam power plant of the Adirondack Power and Light Corporation at Cranesville a few miles west of Schenectady. The writer was traveling west in the night and had just climbed into his berth in the sleeper after leaving Albany:

" 'I raised the shade and watched the country-side flash by through the night.

" Suddenly, the darkness was broken and there shot into view a dazzling white structure, beautiful in proportion and outlined against the darkness like a white-hot ingot. Below, the reflection of the floodlighted building lay inverted in the still waters of the Mohawk. The effect was marvelous. That fairy-like white structure glowing against the dark sky must have impressed itself unforgettably on the minds of every one that saw it.

" 'And to one who, for many years, has been interested in power-plant work, it is gratifying to know that this building was a power plant—the Amsterdam Power Station of the Adirondack Power and Light Corporation.'

"The wide publicity which has attended this publication may be appreciated when it is known that the Literary Digest thought the experience unique enough to reprint it.

"The lesson should not be lost upon cities that the public gets its impression largely from appearances as people rush through. Especially is this true of passengers on trains who get only a flash as the train speeds through. That one flash, however, leaves a lasting imprint—either of tin cans, refuse and tumble-down wrecks of structures along the tracks, or of well kept buildings and grounds that show some idea of civic pride.

"It is as easy to create in the public mind the one impression as the other. The public gains its impression of the character and standing of a man, a house, a factory, a neighborhood or a city by outward appearances. To a greater extent than most people realize, these outward impressions are final. They are the only impressions that the majority of the people ever receive. Unless they are favorable, the idea that will prevail will be unfavorable.

"The Adirondack Corporation chose to make its plant at Cranesville attractive. The officials knew it would be conspicuous. Inasmuch as it would be visible to thousands and millions who yearly travel the Mohawk valley, they believed it worth while to create a favorable impression. That they have succeeded should impress others with the value of outward appearances."

Tests on Stream-Line Stacks

DETERMINATION OF AIR FLOW, POWER USED FOR INDUCED DRAFT AND EFFICIENCY. BY EMILE PRAT AND L. C. WHITON, JR.*

DURING the last 10 yr., the use of induced draft has developed rapidly and it is becoming better known that to predict operating conditions properly, induced draft must be considered as a system of ducts, fan, breeching and stack, rather than as a fan only.

Methods of procedure in experiments to obtain dependable information for the calculation of induced draft systems, are discussed in what follows. The work was done in connection with the type of induced draft originated in Europe, and now becoming better known in this country, which is commonly known as the Evasée, Prat or stream-line stack. This form of induced draft is of two varieties: One utilizing the ejector principle† and the other with the fan handling all of the gas and incorporated within the base of a divergent stack.

PRINCIPAL SYSTEMS OF INDUCED DRAFT

Primarily, the problem of induced draft is to circulate a given volume of gas through a given circuit in which are certain resistances in the form of boilers, furnaces, heat recuperators and ducts. High ratings, which are customary in modern practice, and low temperatures of the flue gas have made natural chimney draft insufficient for present needs, so that the mechanical handling of the gas has frequently become necessary.

Principal types of mechanical induced draft are the following: 1. Where all of the gas is handled through the fan blades and then blown into a stack for discharge to the atmosphere. 2. Ejected draft, based upon the principle of the ejector, where the ejecting fluid communicates a part of its mechanical energy to the ejected fluid.

Arrangement of the fan with respect to the other members of the system is a matter of importance from the standpoint of efficiency and the installation should avoid resistances as shown in Fig. 1, where they have been reduced to the least possible.

In the ejected draft method, care is also required in engineering design, to achieve proper efficiency. For example, use of steam as the ejecting fluid is costly from the standpoint of power; use of cold air as in Fig. 2 (commonly called "out-of-circuit" draft), is a considerable improvement over steam; the most efficient arrangement, however, for this type of draft is "in-circuit" draft, Fig. 3, in which a portion of the gas to be discharged is used as the ejecting fluid, thus reducing the quantity of fluid to be entrained. This arrangement avoids ducts outside the stack with their attendant turns and friction.

CHARACTERISTICS OF INDUCED DRAFT

Draft required at the entrance of the fan is determined by the resistances of the boiler-recuperator-duct system. This varies approximately as the square of the amount of gas to be handled, assuming that, as is usually the case, there is no modification of the physical form and dimensions of the system.

For such a system, the "equivalent orifice," or surface area which, connected to a perfect nozzle, would deliver the same volume of gas Q at pressure p, will be given by the expression

$$(1) \quad A_o = Q \div (60 \sqrt{2g \times p \times 5.197 \div d})$$

Where

A_o is the orifice area in square feet.

Q is the volume of gas in cu. ft. per min.

p is pressure in inches of water.

g is acceleration due to gravity.

5.197 is the factor to convert pressure into lb. per sq. ft.

d is the specific weight of gas at working conditions.

This orifice would pass the same volume of gas as the circuit under consideration, hence its name, "equivalent orifice." If the equivalent orifice of the system remains constant, the efficiency of the fan remains constant, regardless of the quantities of air handled and the pressure produced.

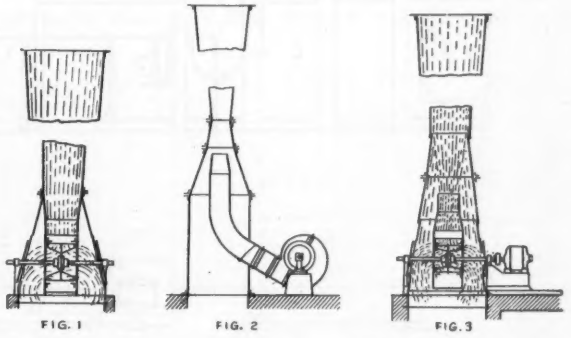


FIG. 1. THIS ARRANGEMENT OF FAN GIVES LOW RESISTANCE FOR INDUCED DRAFT

FIG. 2. "OUT OF CIRCUIT" ARRANGEMENT MIXES COLD AIR WITH THE GASES

FIG. 3. EJECTED DRAFT IS BEST ARRANGED IN THIS WAY

From the above it will be seen that the efficiency of a mechanical draft system depends only upon the equivalent orifice of the system with which it is being used and a curve indicating the values of this efficiency in functions of the equivalent orifice will be the characteristic curve for the system of draft. A knowledge of this curve makes it possible to calculate the power that will be absorbed under given conditions or to choose apparatus of the most favorable size.

To determine completely the operation of the fan, it is necessary to know further the manometric efficiency which is defined by the relation:

$$(2) \quad Em = (g \times p \times 5.197) \div (V^2 \times d)$$

This permits us to calculate the tip speed V of the fan in functions of the pressure to be supplied.

Like the efficiency of the fan, the manometric efficiency is a function of the equivalent orifice and the corresponding curve is also a characteristic of the fan. These two curves permit us to study the operation of a fan in any given case, attention being given to the following facts.

*Of the Prat-Daniel Corp., New York City.

†It might be added that the ejector form of draft has been considerably improved in the last few years and, although in principle it is the same as the so-called Venturi Stack, first introduced by Louis Prat in 1892, it is now somewhat different in design.

Fan Size Varies with Actual Conditions

For a given weight of coal, the volume of flue gas produced will be proportional to its absolute temperature and inversely proportional to the CO_2 content. The latter can be predicted only approximately at the time that the fan is being calculated. Since in actual practice the draft required is also subject to variations, that equivalent orifice which may be the most desirable under operating conditions is often far from that determined by the designing engineers.

To bring this out more clearly, the following is a specific example: The design indicates that the steam generator will operate with 9 per cent CO_2, the gas will be 347 deg. F. and the draft loss of the system 1.575 in. In actual practice the following results are obtained: 8 per cent CO_2, 437 deg. F. and 1.38 in.

is required to furnish only a draft of $p - p_n$ in case p_n is furnished as natural draft. The equivalent orifice upon which the fan works will then have a value equal to

$$(3)\quad A'_o = Q \div (60\sqrt{2\,g \times (p - p_n) \times 5.197 \div d})$$

This is larger than the orifice A'_o which has been indicated above. Furthermore, because of the fact that the natural draft remains relatively constant, whereas the other factors vary proportionately, the orifice A'_o varies with the rating at which the boiler is being operated, whereas A_o remains constant. According to the above reasoning, the overall efficiency of the system and its manometric efficiency will vary at the same time that A'_o varies. In other words, they also depend upon the rating at which the boiler is being operated.

Care should be taken not to confuse the efficiency of the fan with the efficiency of the entire mechanical

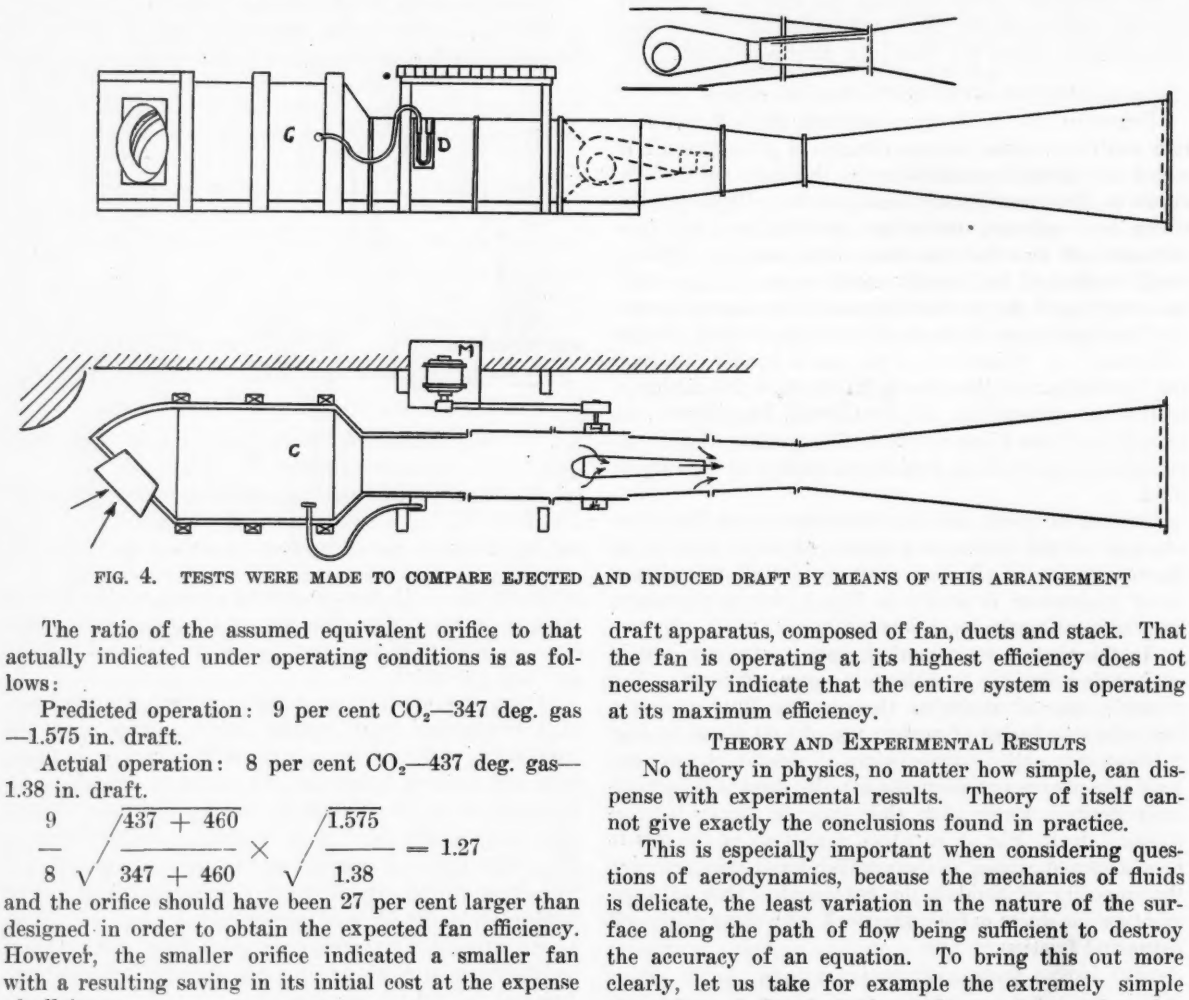


FIG. 4. TESTS WERE MADE TO COMPARE EJECTED AND INDUCED DRAFT BY MEANS OF THIS ARRANGEMENT

The ratio of the assumed equivalent orifice to that actually indicated under operating conditions is as follows:

Predicted operation: 9 per cent CO_2—347 deg. gas —1.575 in. draft.

Actual operation: 8 per cent CO_2—437 deg. gas—1.38 in. draft.

$$\frac{9}{8}\sqrt{\frac{437 + 460}{347 + 460}} \times \sqrt{\frac{1.575}{1.38}} = 1.27$$

and the orifice should have been 27 per cent larger than designed in order to obtain the expected fan efficiency. However, the smaller orifice indicated a smaller fan with a resulting saving in its initial cost at the expense of efficiency.

It is, therefore, prudent to realize that a given set of conditions may indicate an ideal fan size but that in practice the conditions will be changed so that the fan may no longer be the one ideally suited for the work. Therefore, safety factors and initial investment must also be taken into consideration.

It is necessary to take into account in these calculations the influence of natural draft. For a draft, p, at the base of the stack, the mechanical draft apparatus

draft apparatus, composed of fan, ducts and stack. That the fan is operating at its highest efficiency does not necessarily indicate that the entire system is operating at its maximum efficiency.

Theory and Experimental Results

No theory in physics, no matter how simple, can dispense with experimental results. Theory of itself cannot give exactly the conclusions found in practice.

This is especially important when considering questions of aerodynamics, because the mechanics of fluids is delicate, the least variation in the nature of the surface along the path of flow being sufficient to destroy the accuracy of an equation. To bring this out more clearly, let us take for example the extremely simple case of an induced draft outfit consisting of a fan wheel, inlet boxes and discharge opening. It is well known that it is sufficiently difficult to calculate, with extreme exactness, the characteristics of operation of the fan alone. Nevertheless, assuming that the knowledge of these fan characteristics is based upon previous experimental results and that they are, therefore, accurate, then the addition of the other two portions, namely, fan inlet boxes and discharge openings, which which bring into play changes of direction, changes of

section and different obstacles which are part of the construction, will modify considerably the fan characteristics. Although it is possible to calculate with fair accuracy the resistance which is due to a turn or a change of section, when these have simple geometric forms, that is not the case in practice and the results of calculations based upon simple geometric forms are generally quite far from operating results. Therefore, even though theoretical considerations are useful as guides in determining a better form of induced draft, it is imprudent to accept the results of these calculations without verifying them in actual practice.

Draft produced by the ejector system is even more subject to variation from the theoretical determinations.

Several theories of the operation of ejectors for the production of draft have been proposed but the fundamental equation which expresses the conditions existing in the mixing throat (that is to say, that part situated between the end of the ejector and the throat of the divergent portion) has never been expressed accurately in technical literature. As a matter of fact, the variation of pressure in the mixing throat has been completely ignored, assuming that this pressure is constant. In reality, the throat does not function under these conditions and the only method of accurately determining the operation is by actual experience, rather than by theorizing.

Examples of Experimental Study

As a first example, take the results of the experiments on mechanical draft which were made at Belfort, France in 1920 by the Etablissements Prat-Daniel of Paris, in the Shops of the Société Alsacienne de Constructions Mecaniques. These tests had the object of studying the operation of the ejector form of draft in connection with a divergent diffuser, forming one type of Evasée or stream-line stack; also to compare this with induced draft where all of the gas was handled by the fan in the same stack, with conditions as much alike as possible in the two cases. A stack was built of the stream-line type and, as indicated in Fig. 4, was placed horizontally. By means of adjustable connections, this apparatus could have the dimensions of the ejector nozzle or the throat modified; or the ejector could be connected directly with the diffuser so as to convert the ejected draft arrangement into full induced draft as shown at the top in the small detail.

Air was drawn into a box, which was lined with a soldered zinc lining so as to avoid leaks, also equipped with a calibrated inlet. The fan was operated by a belt by means of a direct-current electric motor which had previously been calibrated. Suction in the box was measured by means of a differential manometer capable of accurate readings.

Determination of Quantity of Air

Inlet into the box had an angle of 30 deg. and its coefficient was very close to unity but the speed of the air in the box was so reduced that the velocity pressure of the gas was negligible. Under these conditions Q, the cubic feet per minute of gas, could be determined as a function of the section in square feet S of the inlet opening in the box, equivalent to A_o and the pressure p in inches of water within the box, according to the formula (1) solved for Q:

$$(4) \qquad Q = 60 \times S \sqrt{2\,g \times p \times 5.197 \div d}$$

Determination of Power Absorbed

The motor was calibrated beforehand, hence the power required at the fan shaft could be determined by deducting the loss of power due to the belt transmission, this loss being found from slippage tests. Each determination of power was accompanied by a determination of speed. Measurements were made with inlet openings to the box of different sections, thus permitting the calculation of the overall efficiency of the induced apparatus as a whole for various given equivalent orifices. This also gave the ratio of the useful energy, $Q \times 5.197 \times p \div 33{,}000$ to the power absorbed, hp., at the fan shaft from the following equation for efficiency of the system.

$$(5) \qquad E_s = Q \times p \times 5.197 \div (33{,}000 \times \text{hp.})$$

Results of measurements mentioned above also made it possible to determine the manometric efficiency.

It was thus possible to determine the characteristic curves for the ejector form of draft with different ratios

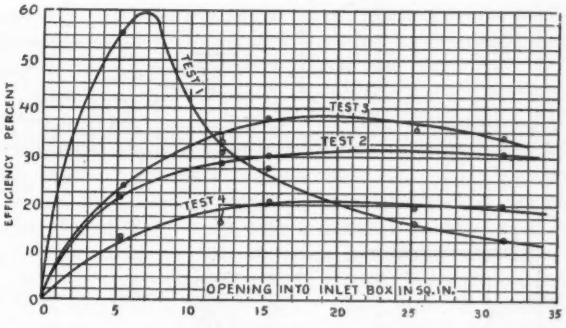


FIG. 5. INDUCED DRAFT HAS HIGH EFFICIENCY OVER A LOW RANGE. FOR EJECTED DRAFT, THE LARGER THE EJECTOR PIPE THE BETTER

of size of jet and size of throat and the same apparatus permitted the determination of the characteristics of the apparatus for full induced draft, i. e., when all of the gas, instead of a portion, was handled by the fan.

Efficiency curves corresponding to these different tests are shown in Fig. 5. Test No. 4 was for the ejector type of stack with the greatest difference of any of the tests between the size of the nozzle of the ejector tube and the throat of the stack.

In Test No. 2, the size of the nozzle of the ejector tube was increased, the throat dimensions remaining constant.

In Test No. 3 the nozzle was still further increased and in Test No. 1, the nozzle was made to coincide with the size of the throat, giving full induced draft. From these curves, it will be observed that the efficiency of the apparatus increased as the ratio between the size of the nozzle of the ejector pipe and the throat decreased. Curve 1 shows that, when the fan handled all of the gas and no ejector system of draft was used, it must operate under more limited conditions in order to obtain its high efficiency, than is the case with the ejector form of draft shown in Curves 2, 3 and 4.

The latter will handle comparatively large or small quantities of gas with the same draft-producing system

without appreciable variation in the efficiency of the apparatus. Another viewpoint to take of this is that the equivalent orifice corresponding to maximum efficiency of the system covers a greater number of conditions with the ejector form of draft than with the stream line form of stack, in which all of the gas is handled by the fan. For a given orifice the fan would, therefore, be larger for induced draft than for ejected draft.

As a second example, will be described the method of procedure in an extensive series of tests which were run in 1924 by the Research Department of the Etablissements Prat-Daniel, first at its own laboratories, then at the Conservatoire des Arts Et Metiers in Paris (similar to the Bureau of Standards of the United States). The object of these tests was to investigate the streamline form of stack in which all of the gas was handled by the fan. It was desired to determine the point where the best efficiency of the system could be obtained, consistent with reasonable size and cost of construction.

formula (4) for Q, using 0.64 as a coefficient of discharge, S being the area of the square inlet opening.

The pressure was measured at the base of the stack.

The power absorbed at the fan shaft was the input × motor efficiency × belt efficiency.

The overall efficiency of the stack was found by formula (5).

The overall manometric efficiency of the stack was found by formula (2).

The equivalent orifice was given by formula (1).

These tests showed the necessity of placing in the aspiration box opposite the inlet a plate for breaking the current and indicated several difficulties, such as determining the power with sufficient exactness, insufficient lagging of the differential manometer, lack of certainty as to the coefficient of discharge of the thin-walled orifice and the effect of unknown leaks into the inlet box.

For this reason it was decided to repeat the tests in the well-equipped mechanical laboratory of the Con-

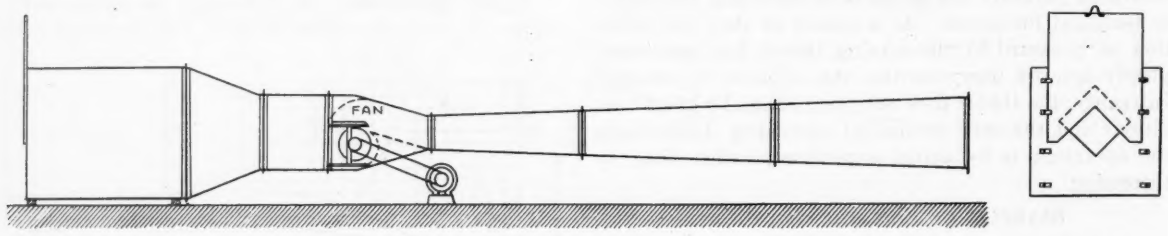


FIG. 6

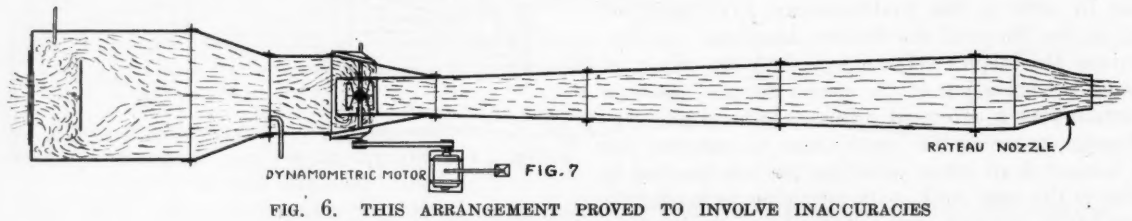


FIG. 7

FIG. 6. THIS ARRANGEMENT PROVED TO INVOLVE INACCURACIES
FIG. 7. IN THIS ARRANGEMENT ACCURACY WAS SECURED

In the first series of tests, which were run at the Research Laboratory of the manufacturer, the stack was placed horizontally, and was connected to a large inlet chamber constructed of riveted steel plate with a square inlet having thin edges and capable of being regulated in size. Figure 6 shows the arrangement used.

For each change of opening into the inlet box, the following measurements were taken: 1. The temperature of the air at the inlet measured by a calibrated mercury thermometer. 2. Barometric pressure. 3. Static pressure in the inlet box at the point A, Fig. 6, with an adjustable Pitot-Ritter tube and a differential manometer using two liquids (oil and colored water). This manometer was checked for each series of measurements by an inclined tube manometer using water. The speed of the motor and that of the fan were measured by a Hasler Tachometer. Power absorbed by the motor was measured by a Chauvin-Arnoux wattmeter.

From these measurements the following was deduced:

The specific weight of the air was determined from the temperature, pressure and hygrometric state.

The quantity of air handled was determined by the

servatoire des Arts Et Metiers and to use every precision apparatus it was possible to have. In the new series of tests, the stack was again placed horizontally and the air was drawn into an inlet box of steel plate but the following improvements were made in the set-up:

The power was measured directly by means of a dynamo-metric motor, the speed being measured simultaneously with the power measurements and all electrical measurements thus eliminated.

The pressure was measured by means of an inclined water-tube manometer, carefully constructed and checked by means of a manometer with a micrometer screw capable of reading to a fraction of a millimeter.

The coefficient of the square, thin-walled orifice was determined for different openings of this orifice by the following method: The outlet at the end of the stack was equipped with a section having a coned cylindrical form, as indicated by Rateau, and with a coefficient equal to unity, as shown in Fig. 7.

The quantity of air Q was measured at the outlet of this opening by means of a Pitot tube placed at different sections of the opening, thus giving the speed of the air at the center and at various sections. Hav-

ing thus determined the quantity of air handled and also the static pressure p in the inlet box at that point where the inlet box decreased in size to join the stack, it was possible to determine the coefficient m for the orifice of the inlet box by means of the following equation:

$$(6) \qquad Q = m\, S_o \sqrt{2\,g \times p \times 5.197 \div d}$$

From this the value of m was observed to vary from 0.63 for a square orifice of 13.8 in. along each side, to 0.61 for a square orifice of 31.5 in. along each side. The quantity of air handled was previously corrected for small leaks which occurred at the joints of the box and where the shaft entered the stack, these leaks being measured for different negative pressures within the box by closing the inlet opening to the box and determining the quantity of air issuing at the outlet of the stack by placing a nozzle at this point. This nozzle was removed, of course, when the tests were run.

Determinations which were thus made for measuring, as closely as possible, the quantity of gas passing through the square thin-walled opening have a general

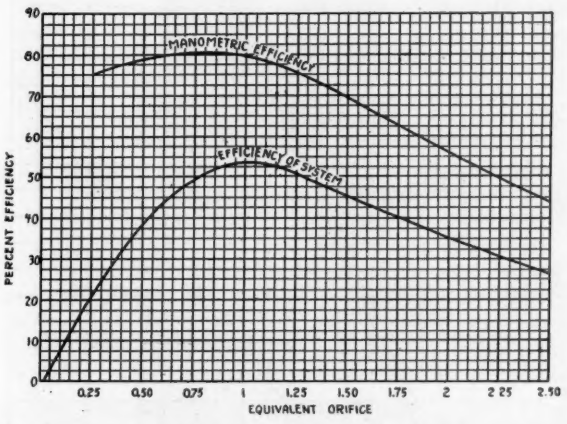


FIG. 8. EFFICIENCIES VARY WHEN THE EQUIVALENT ORIFICE OF A SYSTEM IS CHANGED DUE TO VARYING CO_2, FLUE GAS TEMPERATURE OR DRAFT PRESSURE

interest, because observations on the passage of gaseous fluids through large openings are somewhat rare. Ordinarily, extrapolation from determinations made with liquids or with small orifices is resorted to.

It is for this reason that the coefficient 0.65, which was determined by Ser in 1885, is often used. Ser arrived at this value from the previous works of Peclet and d'Aubuission on the "Flow of Liquids." Recently, Zeuner also has indicated a coefficient of 0.64 and has noted that the speed in the contracted section was actually less by three per cent. The theoretical speed $1096\sqrt{h}$ was due to friction along the walls and impact in the convergent section. The coefficient of discharge of the orifice is, therefore, 0.62, according to him. It is interesting to note that the coefficient of discharge corresponding to a flow of liquid through a small orifice appears to be the same for the flow of a gas through a large orifice.

Total pressure at the base of the stack which enters into the calculation of its efficiency was measured, independently of static pressure, in the inlet box.

Fan efficiency and the manometric efficiency were calculated for each orifice, as indicated previously and the necessary elements were thus present to establish characteristic curves for the stack. Figure 8 shows at unity value on the horizontal the efficiencies when the fan was operating exactly upon its equivalent orifice. As the quantity of gas and the pressure were changed, the equivalent orifice changed. Thus, if the equivalent orifice should be 25 per cent larger but the same fan was used, the fan efficiency would drop to that for the point indicated at 1.25 on the horizontal. These curves at given ratings are sufficient for calculating all forms of stacks of the same type; that is to say, those which have proportional linear dimensions, and the same geometric form.

Business Cycles

BY THE term Business Cycle is usually meant the ups and downs in business, a cycle covering the time from one depression through the recovery, expansion, a period of prosperity, and then a period of recession to another business depression. One of the great efforts of economists at the present time is to smooth out the business cycles, so as to avoid periods of depression and over-expansion, and to keep business moving so far as possible on an even reel.

Results from a recent investigation by the National Bureau of Economic Research discloses that these business cycles are a product of economic organization which has been in existence for less than 200 yr. in Western Europe and, in other regions, for even a shorter period. Analysis of these cycles over a duration of 136 yr. to 36 yr. depending on the statistics available and for 17 countries, shows that they vary greatly in length according to conditions, having run in the United States from a year in length in 1845 and 46 up to 9 yr., from 1873 to 1882.

On the average, however, the business cycle in the United States has run for about 4 yr., ten of the 32 cycles recorded having been 3 yr. in length, five, 4 yr. in length, and six, 5 yr. in length.

For England, the variation has been from 2 yr. up to 10 yr. in length, with the average 5.8.

In the summary so far available, there seems to be no evident laws which govern the length of these cycles for the different countries but, of course, economic conditions such as wars, crop failures and the like will have a bearing in any given country. In any effort to forecast the probable duration of future business cycles, special conditions not likely to occur again should be neglected but special conditions which are likely to recur should, of course, be taken into account.

Studying conditions over a period of years, Dr. Wesley C. Mitchell, finds that the average length of cycles has increased in France and in England, decreased in Germany and has remained practically constant in Austria and in the United States. Statistics for other countries do not go back far enough to make it possible to check the probable tendency as to the length of business cycles.

As an index to probable future happenings, it is interesting to note that practically one-third of the business cycles in the United States have been 3 yr. in length, so that, other things being equal, it would seem that this is the likely period of duration.

Steam Turbine Development Since 1900

By Claude C. Brown

FIGURE 1 sets forth graphically the trend of steam turbine development over the period from 1900 to date, from the standpoint of steam economy, steam temperatures, steam pressures and unit capacities, as experienced in the actual operation of a number of plants which were installed in various years.

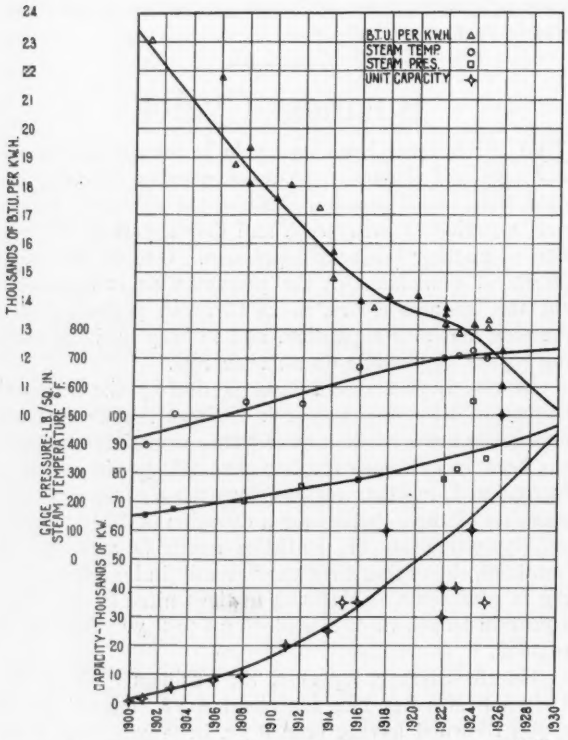


FIG. 1 TREND OF TURBINE DEVELOPMENT SINCE 1900

The data used in the preparation of these curves was taken for the following plants.

1900. 500 kw. General Electric Shops.
1901. 1500 kw. Hartford Electric Light Co.
1903. 5000 kw. Commonwealth Edison Co.
1906. 5000 kw. Potomac Electric Co.
1906. 8000 kw. Commonwealth Edison Co.
1907. 7500 kw. New York Edison Co.
1908. 9000 kw. Buenos Aires Electric Co.
1908. 9000 kw. Pacific Gas & Electric Co.
1909. 9000 kw. Public Service Corp'n. New Jersey.
1910. 10,000 kw. Great Western Power Co.
1910. 12,000 kw. Pacific Light & Power Co.
1911. 20,000 kw. New York Edison Co.
1912. 20,000 kw. Commonwealth Edison Co.
1913. 10,000 kw. Tricity Ry. Light & Power Co.
1914. 22,000 kw. Brooklyn Edison Co.
1914. 25,000 kw. Commonwealth Edison Co.
1915. 30,000 kw. Commonwealth Edison Co.
1916. 35,000 kw. Boston Elevated Railway Co.
1917. 20,000 kw. Buffalo General Electric Co.
1918. 60,000 kw. Interborough Rapid Transit Co.
1919. 40,000 kw. Detroit Edison Co.
1920. 30,000 kw. Interborough Rapid Transit Co.
1922. 40,000 kw. United Elec. Lt. & Power Co.
1922. 35,000 kw. United Elec. Lt. & Power Co.
1922. 30,000 kw. Detroit Edison Co.
1923. 40,000 kw. Gennevilliers, Paris.
1924. 50,000 kw. Brooklyn Edison Co.
1924. 60,000 kw. Commonwealth Edison Co.
1925. 15,000 kw. Lansing, Mich. Municipal Elec.
1925. 35,000 kw. Southern California Edison Co.
1926. 100,000 kw. Brooklyn Edison Co. (Builders estimate.)

Figure 2 sets forth the daily fuel oil consumption for various daily plant outputs for two western steam generating plants. The data used for the preparation of these curves was obtained from the operating records of the two plants in question.

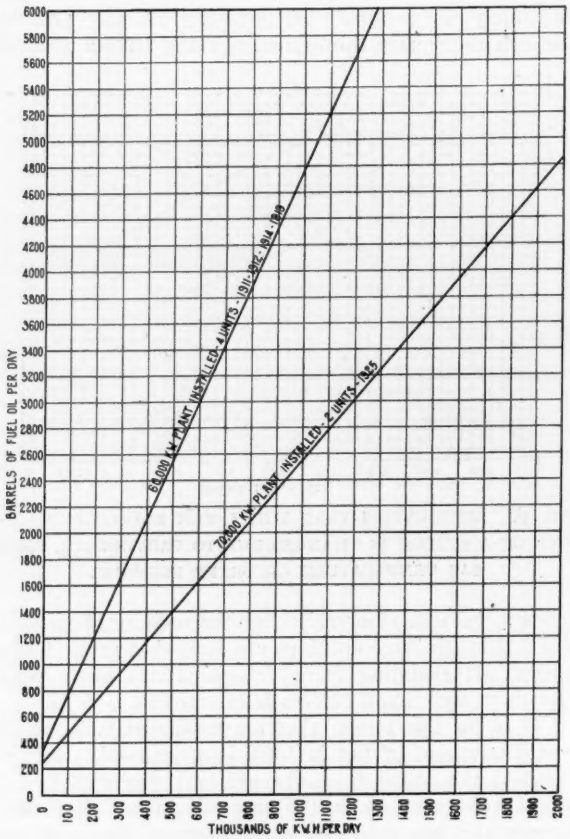

BARRELS OF FUEL OIL PER DAY
THOUSANDS OF K.W.H. PER DAY
60,000 KW. PLANT INSTALLED: 4 UNITS - 1911-1912-1914-1919
70,000 KW. PLANT INSTALLED: 7 UNITS - 1925

FIG. 2. DAILY FUEL OIL CONSUMPTION FOR VARIOUS DAILY PLANT OUTPUTS OF TWO STEAM PLANTS

The 60,000-kw. plant was originally composed entirely of steam engine-driven generators. As the demand on the plant increased the oldest of the engines were replaced with steam turbines of the General Electric Curtis vertical type. The first replacement was made in 1911 at which time a 12,000-kw. unit was installed. In 1912 and 1914 two 15,000-kw. vertical units were added and more of the old engines removed. Finally in 1919 a 15,000-kw. horizontal unit took the place of the remaining engines. The plant is used essentially as a standby plant but at times is called upon to carry

capacity load. It is operated in parallel with hydro and due to this fact it is necessary to keep the boilers hot in order that the hydroelectric load may be picked up upon short notice. The fuel requirements of this plant are 330 bbl. of fuel oil per day to keep the boilers hot plus kw.hr. ÷ 225 bbl. of fuel oil for the load carried.

The 70,000-kw. plant was installed new in 1925, the entire equipment being of the latest approved design. This plant is also essentially a standby plant operated in parallel with water power, and it also is called upon to deliver capacity load at times. The fuel requirements of this plant are 250 bbl. of fuel oil per day to keep the boilers hot and an additional kw.hr. ÷ 433 bbl. of fuel oil for the load carried.

Quantity Production of Larger Diesels Under Way

NEW UNITS OF 480, 600 AND 720 HP. OFFERED BY FAIRBANKS, MORSE & CO. TO MEET DEMANDS OF INDUSTRY FOR QUANTITY PRODUCTION OF LARGER ENGINES

RAPIDLY GROWING use of Diesels in both the marine and stationary field has resulted in a greater demand for larger engines. Consequently, the range of ratings which will warrant quantity production has also increased and Fairbanks, Morse & Co. has developed a new two cycle, airless injection engine to meet these demands. Four, five and six cylinders of 120 hp. each are used to make units of 480, 600 and 720 hp.

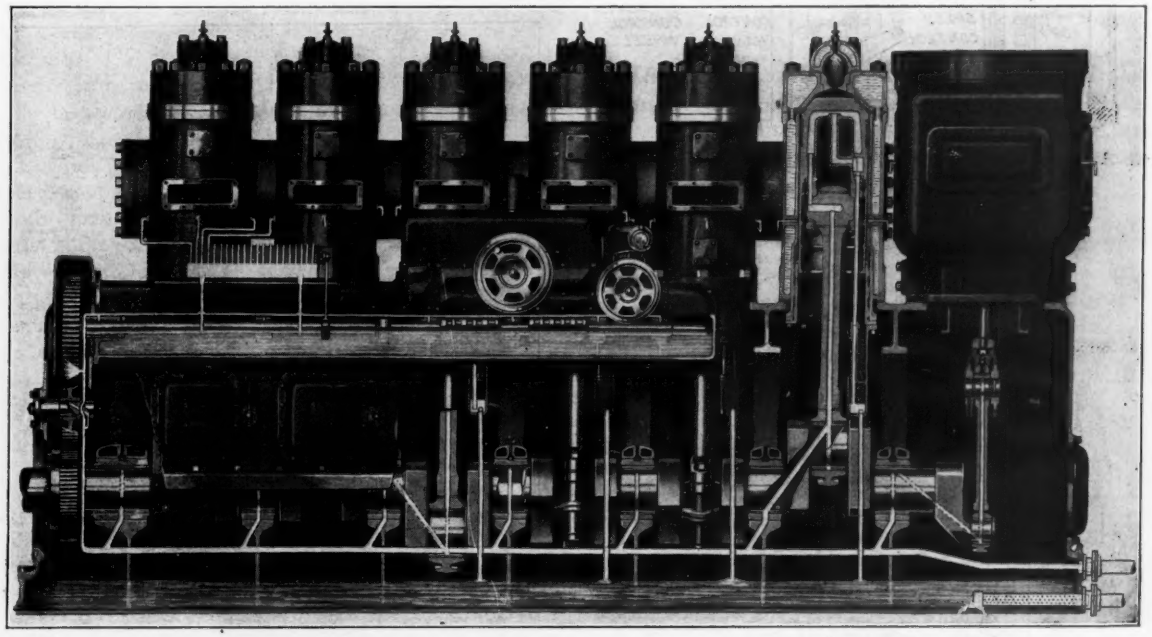


FIG. 1. LONGITUDINAL SECTION OF ENGINE SHOWING CONSTRUCTION, GENERAL ARRANGEMENT AND OILING SYSTEMS

Two stage combustion, pressure lubrication, oil cooled pistons, centralized control and a built-in scavenging air pump are incorporated in the design to give a compact, sturdy, economical engine. Compression is carried to 500 lb. and the fuel injected by a pump actuated from a layshaft. The layshaft, visible in the longitudinal section of the engine, Fig. 1, is geared to the main shaft. Each cylinder has its own fuel injection pump unit bolted to a common pump housing. Driven by a flexible bevel gear drive, the flyball governor, Fig. 2, acts through a series of levers to regulate the effective length of the injection stroke by seating the suction valves at the proper time.

Complete control is provided through a compact unit located near the center of the engine with starting controlled in three steps by means of the larger hand-wheel. Two double seated master air starting valves each control a unit of three cylinders. Normally rollers for the individual air starting valves shown in Fig. 3 are held disengaged from the cams by a spring. When the starting wheel is turned to the first step position, however, the master valves are opened, admitting air to the individual valves and automatically throwing the rollers in contact with the operating cams. Starting air is used on all cylinders during this period and the fuel pump arranged to inject a full charge of fuel into the combustion chamber. As soon as the engine turns over, the wheel is swung to the second position, closing one master air valve. This stops the flow of starting air to half the cylinders and the absence of cold compressed air allows the heat of compression to ignite the oil in these cylinders. As the power impulse speeds up the engine, the wheel is swung to third or "run," position and starting air closed off from all cylinders. Firing becomes regular and the engine comes under control of the governor.

Air trapped between the master and individual air starting valves escapes slowly through a hollow stemmed rod, relieving the pressure and allowing the springs to disengage the air starting rollers. For reversing engines a few simple parts are added to the control with

the shaft carrying the starting air valve rockers and rollers arranged to be moved longitudinally to engage the ahead or astern cams as desired. As a safety measure, in case the engine has not quite stopped when the

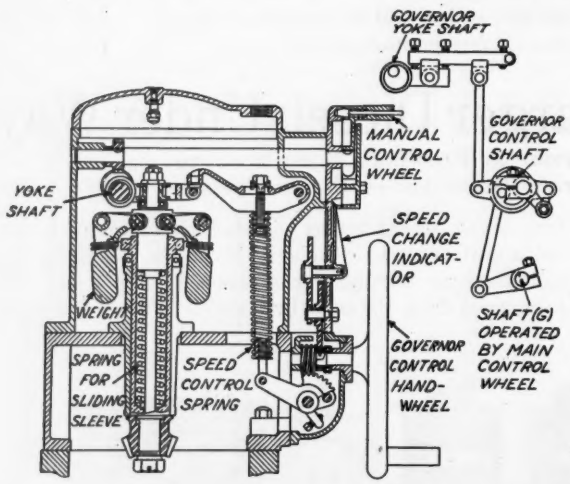


FIG. 2. TWO METHODS OF SPEED VARIATION ARE PROVIDED, BOTH LOCATED ON THE GOVERNOR CASE

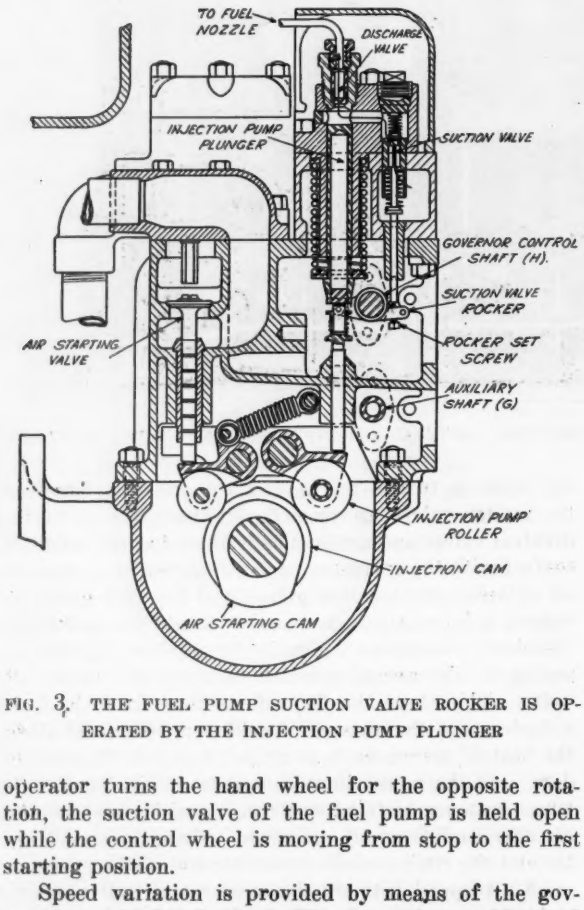


FIG. 3. THE FUEL PUMP SUCTION VALVE ROCKER IS OPERATED BY THE INJECTION PUMP PLUNGER

operator turns the hand wheel for the opposite rotation, the suction valve of the fuel pump is held open while the control wheel is moving from stop to the first starting position.

Speed variation is provided by means of the governor control hand wheel, Fig. 3, or for rapid speed changes through the manual control wheel shown above the governor control hand wheel in the same illustration. The latter wheel operating through the governor control linkage has immediate effect on the speed and when this control is used, the governor acts simply as an overspeed device. Fuel oil is supplied to the suction of the injection pump from a small reservoir located above the pump housing. The auxiliary fuel pump is driven by an eccentric from the camshaft and the overflow from the reservoir returned to the auxiliary pump suction.

Pressure lubrication is used throughout. Oil taken from the crankcase sump by a rotary pump is strained, cooled and forced through the system as indicated in Fig. 1. Entering the main bearings the oil flows through the hollow connecting rods to the wrist pins and pistons returning to the crankcase through a telescope joint. Three point cylinder lubrication is used and four wiper rings provided in the low part of the piston collect and drain cylinder oil, which works past the piston, away from the sump to the purification system.

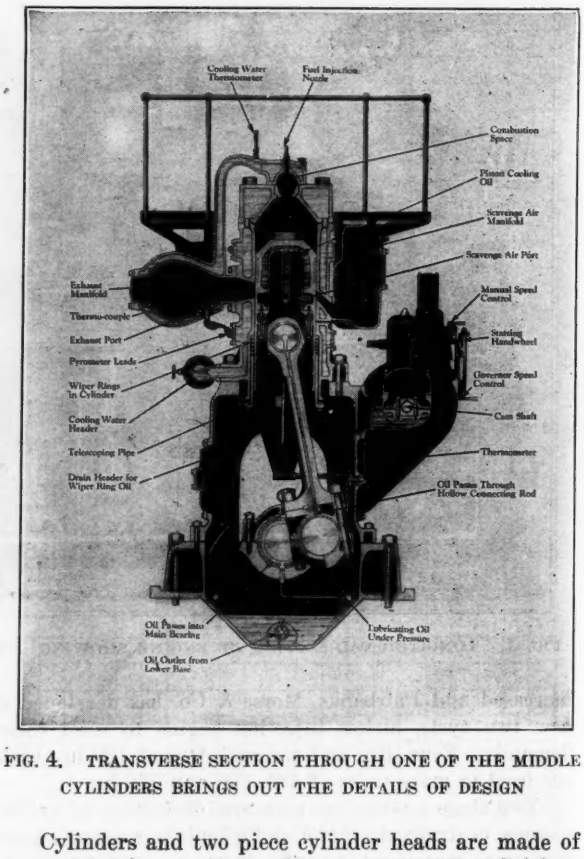


FIG. 4. TRANSVERSE SECTION THROUGH ONE OF THE MIDDLE CYLINDERS BRINGS OUT THE DETAILS OF DESIGN

Cylinders and two piece cylinder heads are made of a special iron containing 20 per cent steel. Castings are symmetrical, completely water-jacketed with the four wiper rings held in place by a sleeve shown clearly in both transverse and longitudinal sections of the engine. This sleeve is held centered by three studs, the oil collecting in the space between the sleeve and cylinder to be carried to the purifying system by the drain shown in Fig. 4.

Cooling water connections are made by short pipes with individual ring gaskets to eliminate leakage. An air valve is located in the head for the starting air inlet with the fuel injection nozzle located in the upper part of the combustion chamber. A block is also provided for taking indicator cards while a thermometer

well placed in the water jacket facilitates the regulation of cooling water.

TRUNK PISTON BEARING SURFACE IS NOT BROKEN BY WRIST PIN

Aside from the circumferential webs and the shoulder for bolting on the piston pin assembly the piston is an open casting. The piston pin, hub and cooling oil seal are a separate cast steel assembly so that the long trunk piston is free from any break in its bearing surface. Connecting rods are forged from a single billet, solid, non-adjustable at the top with a bronze bushing and shim adjusted at the lower end.

Scavenging air is maintained at about 2½ lb. by a double acting air pump driven by a crank from the main shaft. The water cooled exhaust manifold is made up of two castings connected together at the center by a tee so that the exhaust connection can be taken off from a number of positions. Clean out plates are provided so that both the water jacket and gas chamber can be easily inspected.

To keep the height of the engine above the floor level low, the lower base is designed so that the crankshaft center is but a few inches above the floor. The upper base is cast in one piece with inspection door large enough for a man to enter if necessary. The 720-hp. marine engine has an overall length of 20 ft. 10 in., a width of 7 ft. 11 in. and height of about 10 ft. without hand rails, although a maximum clearance of 17 ft. 6 in. is required above the floor for pulling pistons.

Interesting Tunnel Development at Guernsey Dam

EXCAVATION WORK for the power plant at Guernsey Dam, Wyoming, has just been started. This development, located on the North Platte River, is a Bureau of Reclamation project estimated to cost $2,100,000 and when completed will serve the triple purpose of providing 72,000 acre-feet additional storage for the North Platte irrigation project, give closer control of water released from the Pathfinder reservoir and provide electrical power generation.

Approximately 75 per cent of the work is complete. The dam, a composite structure of gravel, clay and rock, will be 105 ft. high with a crest length of 560 ft. Material was dumped from trestles and sluiced into place, forming a clay core of selected material for water tightness. The section is a 3 to 1 upstream slope with a 26 ft. top width and a 2 to 1 back slope for 40 ft. below the crest breaking at this point to an 8 to 1 slope to the downstream toe.

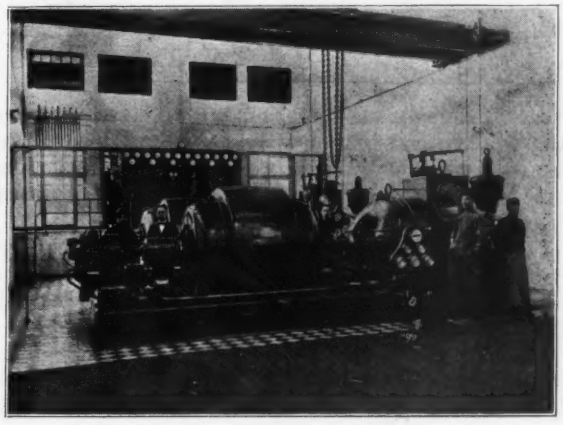
Spillways will be provided at both ends of the dam, a 580 ft. long concrete lined channel with a discharge capacity of 50,000 sec. ft. at the north end will be controlled by a 50 by 50-ft. Stoney roller gate. At the south end two 14½ by 64-ft. automatic drum type gates will control a maximum spilling flow of 30,000 sec. ft. to a 30 ft. diameter diversion tunnel.

Driven through solid rock, a 30-ft. horseshoe section tunnel 1168 ft. in length, lined with 18 in. of concrete, now serves as a bypass, although it will later be used for other purposes. After the construction of the main spillway, this tunnel will be plugged in three places, one at the entrance, one just above the water power tunnel and one just below the penstock. The space between the last two plugs will be used as a desilting chamber and the silt sluiced through three 5 by 5-ft. gates in the lower plug. Water from the south spillway will drop directly into the lower part of the tunnel just below the lower plug.

Water for power generation will be brought to the settling basin through a 12 ft. diameter tunnel 650 ft. long cut through solid rock and lined with 15 in. of concrete. At the lower end of the basin a 22 by 85-ft. surge tank will be provided and a steel penstock will carry the water to the power house under an average head of 70 ft. For the present at least, a 3400-hp. vertical turbine, direct connected to a 3000-kv.a. generator with a direct current exciter, will give sufficient generating capacity to meet the power demands.

Riots Make Turbine Operation Difficult

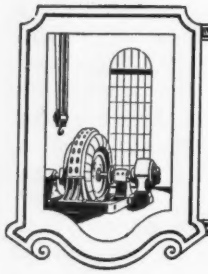
THESE TURBINE-GENERATORS withstand rough usage. They are of Westinghouse make, 750 kw. capacity, and are installed in the Yu Ta cotton mill outside Tientsin,



AMERICAN TURBINES INSTALLED IN CHINESE PLANT

China, where they not only have to survive the minor troubles incident to ordinary turbine operation but they must be able to cope with frequent riots and strikes during which much equipment is damaged.

POWER-LINE insulators and road signs are the favorite targets of the army of hunters which each year take to the field in pursuit of the wily buck. Rifle practice seems essential not only to the small boy with his pet 22 but to the more mature hunter as well. Each year serious damage is done all over the country through the practice of shooting at insulators on transmission lines. Heavy loss and serious inconvenience to those sections dependent upon the lines for service is the result. As a result of overtures from the light and power industry in Michigan, the pamphlet containing the game laws of that state now carries the following warning: "Never shoot at an electric power line. An insulator damaged by a bullet menaces light and property, causes fires and interrupts service upon which thousands depend."



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Automatic Reclosing Equipment in Substations*

PART I.* PRINCIPLES INVOLVED IN THE APPLICATION OF AUTOMATIC D.C. RECLOSING FEEDERS TO MINE SUBSTATIONS. BY A. E. ANDERSON†

AUTOMATIC SWITCHING was first applied in a general manner to 600 v. railway service. The results obtained in this field proved so successful that today application of automatic switching has been extended to any number of other fields. While the underlying principles of automatic switching are similar the practical application to different types of service will vary somewhat depending upon requirements.

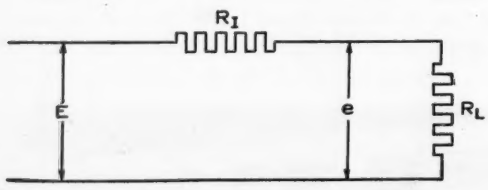


FIG. 1. A COMMON METHOD OF DETERMINING THE VALUE OF AN UNKNOWN RESISTANCE IS TO CONNECT A KNOWN RESISTANCE IN SERIES WITH IT AND COMPARE THE VOLTAGES ACROSS THE RESISTANCES. R_I = UNKNOWN RESISTANCE

Mining and railway switching requirements differ slightly. One difference is that in mining service a part of the load is of a fairly uniform or steady character, being created by pumps, cutting machines, etc. Another difference is that in mining service, the load demand as a whole increases much more rapidly than in the case of railway service. This load characteristic necessitates bringing on the machine within a short time after the indication has been given by the load-responsive devices. In many cases it is desirable to omit the latter device and substitute in its place a time switch or remote control apparatus. In this way the station becomes non-load-responsive to starting or stopping service and is in operation during a fixed period of time.

Automatic reclosing feeders are essential to the successful operation of automatic stations although their use is by no means confined to such stations. Their continued application to manually-operated stations is proof that they provide more prompt and reliable service than the ordinary manually-operated circuit breaker.

After a power interruption, service must be restored within a time that is consistent with good practice. The usual practice in manually-operated stations is to wait a short time and then reclose the circuit breaker regardless of external circuit conditions. After a few such attempts the operator usually waits a longer time before repeating this procedure or waits until the line is reported clear. An automatic reclosing feeder obviates delays incident to such operation. Service is promptly restored after feeder conditions have become normal without any attempt being made to reclose on a heavy overload.

SERVICE REQUIREMENTS

In general, an automatic reclosing feeder for substation service should incorporate the following features: (a) Trip on overload, (b) Reclose after a definite time has expired, (c) Reclose on either stub-end or multiple-feed, (d) The tripping, time delay and reclosing values, should have independent adjustments, (e) The reclosing values for stub-end and multiple-feed should be independently adjustable, (f) The feeder unit should be self-contained and operate from the circuit which it controls.

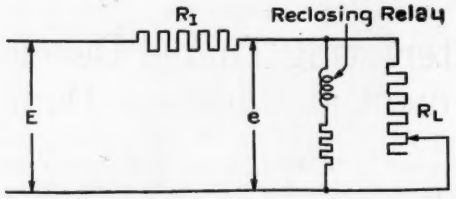


FIG. 2. A RECLOSING RELAY CONNECTED IN PARALLEL WITH THE RESISTANCE OF THE LOAD CIRCUIT

FEEDER CLASSIFICATIONS

A stub end or radial feeder is one which connects a load to its only source of power.

A multiple feeder is one which is connected to a common load in parallel with one or more feeders from independent sources.

A combined stub end and multiple feeder is one which may operate under either one of the two previously mentioned conditions.

Three different schemes, available for use with stub end automatic reclosing feeders, are as follows:

1. Simulation of manual operation
2. Load limiting or load shifting
3. Load indicating or measuring

Simulation of manual operation on stub end feed would require the use of relays which would reclose the breaker a number of times regardless of external

*This is the first of two articles by Mr. Anderson on this subject. The second part will appear in the Nov. 15 issue.

†General Electric Co.

circuit conditions. After a number of such operations were made, the feeder would be locked out or repeat the above cycle after a definite time had elapsed. Either method of operation is objectionable, due chiefly to the fact that in the case of a prolonged short circuit which subsequently disappeared, the feeder would require manual operation before service could be restored or, in the second case, a long time would elapse before service could be resumed. Another objectionable feature, common to both the above methods, is the wear and tear imposed on the equipment by such operation on heavy overload or short circuit conditions.

Load limiting or load shifting resistors have been applied to a limited extent to mining substations. The purpose of such resistors is to transfer a portion of the overload to other stations which are connected to the same feeder. The insertion of a step of resistance on stub end feed reduces the voltage at the load by the amount of drop in the resistor step. The reduced voltage slows down the motors which tends to increase the length of time of the overload. Hence the use of such resistors has a detrimental effect on stub end feed.

Load indicating or measuring has been successfully applied to the measuring of the external circuit on stub end feed. The method consists in comparing an unknown resistance with a known resistance. The operation on multiple feed is simply a matter of closing the line contactor when the voltage difference between the station bus and feeder is less than a predetermined value. The method by which various control circuits, resistance values, relay calibrations, etc., are determined for both stub end and multiple feed is given in following sections.

Principal Features of a Load Indicating Scheme for Stub End Feed

There will be discussed, under the above heading, the method by which various relay circuits, resistance values, relay calibrations, etc., are determined for load indicating operation on stub end feed. The characteristics of equipments using various connections, calibrations, etc., will be shown.

A very common method of determining the value of an unknown resistance is to connect a known resistance in series with it and compare the voltages across the resistances.

Thus in Fig. 1:

E = Voltage across R_I and R_L
e = Voltage across R_L
R_I = Known resistance in ohms
R_L = Unknown resistance in ohms

Since the current in each resistance is of the same value

$$\frac{e}{R_L} = \frac{E}{R_I + R_L} \quad \ldots\ldots (1)$$

from which

$$R_L = \frac{eR_I}{E - e} \quad \ldots\ldots (2)$$

or,

$$R_I = \frac{R_L(E - e)}{e} \quad \ldots\ldots (3)$$

E = Station or bus voltage (D.C.).
e = Voltage across coil circuit of reclosing relay.
R_I = Resistance of load indicating resistor, in ohms.
R_L = Resistance of load circuit, in ohms.

In Fig. 2 there is shown a coil circuit or a reclosing relay connected in parallel with R_L, the resistance of the load circuit. The current taken by the relay coil is negligible compared with that taken by R_L. If the current taken by the relay coil is increased to an appreciable value, it is found that changes in the load resistance do not produce as great a relative change in e, as when this current is of a negligible value.

R_I is the resistance of the load indicating resistor of a type shown in Fig. 3. This type of resistor usually has a negligible temperature coefficient, hence it is assumed throughout this article that its resistance is constant.

In determining the value of R_I it is necessary to know the values of E, e and R_L. A d.c. feeder is usually rated in volts and amperes. Hence, to obtain the value of R_1—

E is taken as the normal (d.c.) voltage of the station.

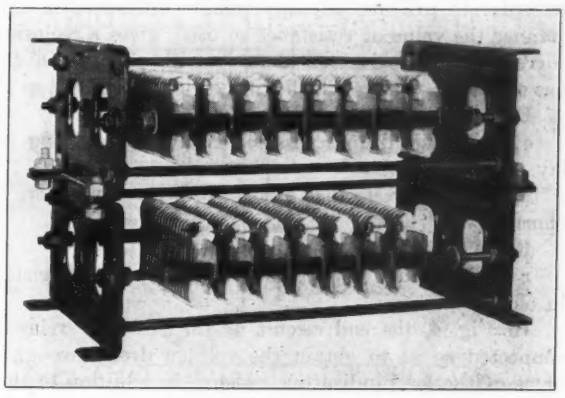


FIG. 3. A LOAD INDICATING RESISTOR FOR A 275-V., 1640-AMP. D.C. RECLOSING FEEDER

e is an approximation of the minimum value at which the reclosing relay will operate. This value for positive operation under service conditions has been found to be 2 per cent of E.

$$R_L = \frac{E}{\text{Rated feeder amperes}}$$

From the foregoing discussion it is seen that equations (1), (2) and (3) still hold for the connections as shown in Fig. 2. Substituting the above values of E and e in equation (3), it is found that—

$$R_I = 49\ R_L \quad \ldots\ldots (4)$$

Dividing both sides of this equation by E and inverting:

$$\frac{E}{R_I} = \frac{E}{49\ R_L} = \frac{E}{R_L} \times 0.0204 \quad \ldots\ldots (5)$$

Equation (5) shows that when a short circuit exists on the feeder, the load indicating resistor limits the current to approximately 2 per cent of the rated feeder current. Calling this value of current 2 per cent of rated feeder current,

(6) $R_I = 50\ R_L$, and substituting in equation (1),

$$\frac{E}{R_L} = \frac{E}{50\,R_L + R_L} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

from which,

$$(8)\quad e = \frac{E}{51} = 0.0196\ E,$$

which is the calibration of the reclosing relay.

The pick-up voltage (e) of the reclosing relay for a given load resistance (R_L), may be increased by using

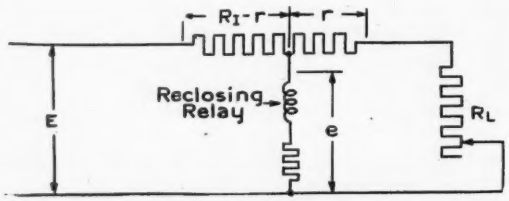


FIG. 4. A RECLOSING RELAY CONNECTED ACROSS A PORTION OF THE LOAD INDICATING RESISTOR

some of the voltage drop in the load indicating resistor. In order to produce any appreciable difference in this manner the value of resistance so used, gives a reclosing current which varies considerably with changes in the bus or station voltage which will hereafter be noted as E.

E = Station or bus voltage (d.c.).

e = Voltage drop across coil circuit of reclosing relay.

R_I = Total resistance of load indicating register, in ohms.

R_L = Resistance of load circuit, in ohms.

r = Resistance of portion of load indicating register, in ohms.

In Fig. 4, the coil circuit of the reclosing relay is connected so as to obtain the voltage drop through r ohms of the load indicating resistor, in addition to that through R_L ohms of the load circuit. Assuming that the resistance of the coil circuit of the reclosing relay is negligible:

$$\frac{e}{r + R_L} = \frac{E}{R_I + R_L} \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

from which,

$$e = \frac{E\,(r + R_L)}{R_I + R_L} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

In order to derive values of the voltage calibration of the reclosing relay for a given set of conditions, it is necessary to substitute values of E, R_I, R_L, and r in equation (10) and solve for e. Values are assumed as follows:

E = 100 v.

R_I = 50 ohms.

R_L = 1 ohm.

r is taken at 0, 1, 2 and 5 ohms.

Having once determined e for a given set of conditions, the effect of variations in the station voltage (E) on the reclosing current can be determined.

Taking the above values, with r = 0 ohms and substituting in equation (10):

$$e = 1.96 \text{ v.} \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Substituting e and R_I in equation (2) in which r = 0:

$$R_L = \frac{1.96 \times 50}{E - 1.96} = \frac{98}{E - 1.96} \quad \ldots\ldots\ldots\ldots (12)$$

Over the ordinary operating range E is large compared with 1.96, so equation (12) becomes

$$(13)\quad R_L = \frac{98}{E}, \text{ or the equation of a hyperbola.}$$

Figure 5 shows a curve plotted from equation (12), by substituting different values of bus voltage, E, and solving for the load resistance, R_L. This curve is practically a hyperbola.

The curve obtained when reclosing on a resistance of R_L ohms may be represented by I, which is called the reclosing current.

$$I = \frac{E}{R_L} \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

combining with equation (12)

$$I = \frac{E(E - 1.96)}{98} \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

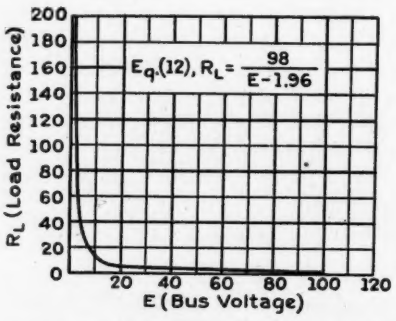


FIG. 5. A CURVE PLOTTED FROM EQUATION (12) SHOWING VARIATION OF LOAD RESISTANCE WITH BUS VOLTAGE

Since E is large compared with 1.96, over ordinary operating range, equation (15) can be written,

$$(16)\quad I = \frac{E^2}{98}, \text{ or the equation of a parabola.}$$

Figure 6 shows how the reclosing current I, varies with the station or bus voltage, E. The values of I are obtained by substituting different values of E in equation (15). This curve approximates a parabola.

Curves of R_L and I plotted against the station or bus voltage, E, for the various reclosing relay connections, have respectively a more or less modified hyperbolic and parabolic form. Referring back to Fig. 4, where the reclosing relay is connected across $(r + R_L)$ ohms, it was found that e, the voltage across the reclosing relay (coil circuit), could be determined by substituting values of E, R_I, R_L, and r in equation (10).

Values will be assigned to E, R_I, and R_L, and r will be varied. From this, e, will be determined. This value of e may then be considered as fixed (as it must be for a given relay calibration) and then E will be varied to note the effect on R_L, the minimum value of load resistance that will produce e volts across the coil circuit of the reclosing relay.

Variations in E, the station or bus voltage, are commonly caused in practice by the use of over or under-

compounded machines. A common compounding for mining service is 250 v. no load to 275 v. full load, with an intermediate value slightly greater than the latter voltage. The current supplied to a load by one of a number of feeders can vary the bus voltage through the above range. This variation will affect the reclosing calibration of some other feeder that may be measuring out its particular feeder circuit.

Values are assigned to E, R_I, R_L, and r, from which corresponding values of e are calculated from equation (10). These values are given in Table I.

TABLE I

Eq. (10) $e = \frac{E(r + R_L)}{R_I + R_L}$

E	R_I	R_L	r	e
100	50	1	0	1.96
100	50	1	1	3.92
100	50	1	2	5.88
100	50	1	5	11.76

If equation (9) is expressed in terms of R_L the following is obtained:

$$R_L = \frac{eR_I - Er}{E-e} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

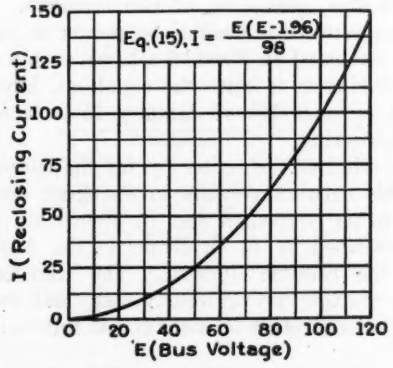


FIG. 6. CURVE SHOWING VARIATION OF THE RECLOSING CURRENT I WITH THE STATION OR BUS VOLTAGE E

Taking corresponding values of e, R_I and r, from Table I and substituting in equation (17), it is possible to express R_L in terms of E, the bus voltage. Curves of R_L against E are given in Fig. 7.

The value of current obtained when reclosing may be found by substituting in equation (14) the values of R_L as obtained from equation (17), with the corresponding value of E. Curves of reclosing current I, against the station or bus voltage, E, are given in Fig. 8.

The curves in Figs. 7 and 8 show that for a given ohmic value of load indicating resistance, a better reclosing calibration is maintained over a varying bus or operating voltage by connecting the coil of the reclosing relay *directly* across the load.

In Figs. 7 and 8 are also shown the values of R_L and I obtained by moving the connections of the reclosing relay towards the center of the load indicating resistor.

Values are assigned to E, R_I, R_L, and r, as in the case above (Table I), from which corresponding values of e are calculated by use of equation (10). These values are given in Table II.

TABLE II

Eq. (10) $e = \frac{E(r + R_L)}{R_I + R_L}$

E	R_I	R_L	r	e
100	50	1	15	31.4
100	50	1	25	50.9

Both values of e as given in Table II are open to criticism. The first step would be to set the reclosing relay so as to permit reclosure on 100 amp. at 100 v., or taking R_L equal to 1 ohm as in Table II and r = 15 ohms, e, the setting of the reclosing relay, is found to be 31.4 v.

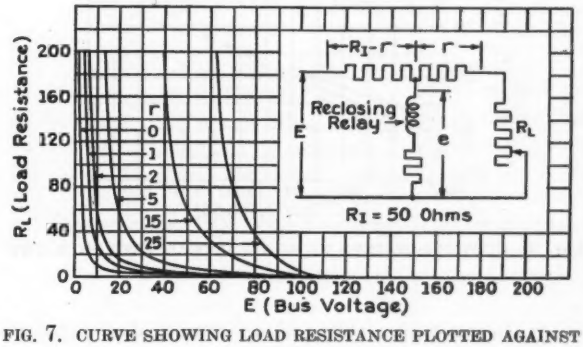


FIG. 7. CURVE SHOWING LOAD RESISTANCE PLOTTED AGAINST BUS VOLTAGE

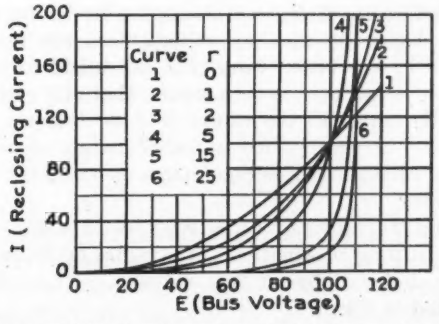


FIG. 8. RECLOSING CURRENT PLOTTED AGAINST BUS VOLTAGE

If the first set of values of R_I, r and e are now substituted in equation (10) and R_L is taken as 0, it is found that E = 105 v. This means that with the preceding connections and relay setting, the breaker would reclose on a short circuit at 105 v., or over, which is not desired.

If the value of e in Table II is increased from 31.4 to 34 v. it is found that E = 113 when R_L = 0. This would permit satisfactory operation up to 110 v., which represents the maximum percentage overvoltage usually assumed in automatic station practice.

Curves shown in Figs. 7 and 8 (where r = 15) are obtained by assuming e = 34 v., and determining the values of R_L and I for different bus or station voltages,

E, by the use of equations (17) and (14). In all cases, $R_I = 50$ ohms.

Reference to Fig. 8, Curve 5, shows that the reclosing value at 100 v. is lower than that obtained in the previous cases as given in Table I, and in Curves 1, 2, 3 and 4 in Fig. 8. Also the reclosing current, I, varies more with corresponding changes in E.

The second set of values in Table II is based on the connection of the relay to the mid-point of the load indicating resistor. In order to reclose on 1 ohm when the bus voltage is 100, the setting of the reclosing relay is found to be 50.9 v. This setting is entirely too low, for if the bus voltage, E, should increase to 102 v., the breaker would reclose on a short circuit. In order to take care of a bus voltage variation of the same degree

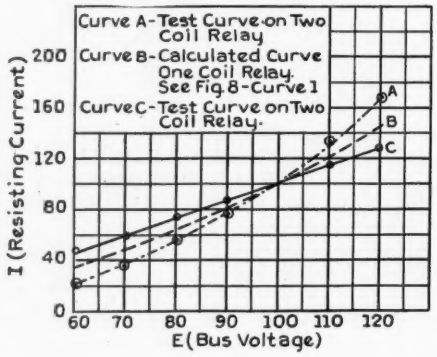


FIG. 9. CURVES OBTAINED FROM AN ACTUAL TEST ON A TWO COIL RELAY

as in the preceding case (where e was taken equal to 34 v.) it is found that the reclosing relay setting is 56 v. This requires that the substation voltage increase to 112 v. before the relay will close the feeder on short circuits; hence, if the bus voltage does not increase over 110 v., the latter value will be satisfactory. It should be noted that it is assumed that the reclosing relay will operate at the values of e as determined in each case. In practice a reasonable margin should be given for variations in voltage values at which the relay will operate.

Taking the values of $R_I = 50$, $r = 25$ and $e = 56$, and substituting in equation (17), values or R_L may be determined for different bus voltages. These values are plotted in Fig. 7.

Values of reclosing current, I, are found by substituting the bus voltage, E, with its corresponding value of R_L in equation (14). These values are plotted in Fig. 8.

It may readily be seen by referring to Fig. 8, that the curves obtained by using a value of r equal to 25 ohms, is steeper than that obtained when $r = 15$ ohms. At rated voltage only 15 amp. may be obtained on reclosure, as compared with 33 amp. when $r = 15$ ohms, or 100 amp. when $r = 5$ ohms.

The results show that in order to apply the load indicating resistor efficiently on stub end feed, the reclosing relay coil should be connected directly across the load. This permits reclosing on a maximum load with the least effect on the reclosing calibration due to fluctuations in bus voltage. In the case of over compounded machines the reclosing calibration will vary considerably if the reclosing relay is connected to the center of the load indicating resistor.

Typical Results Obtained on Stub End Feed

It has been found that a two-coil reclosing relay can be designed and connected so as to give a certain degree of compensation required by variations in bus voltage. Figure 9 shows three curves.

Curve B, taken from Fig. 8, shows calculated variations in reclosing current, obtained from a single coil relay with its coil connected directly across the load. Curves A and C, in Fig. 9, have been obtained from actual tests on a two-coil relay, the tests differing from each other only in the air gaps used. Curve A shows no compensation since it varies greater than curve B. Curve C, taken with a different air gap, shows that compensation may be obtained so that the reclosing current varies nearer in proportion to the bus voltage.

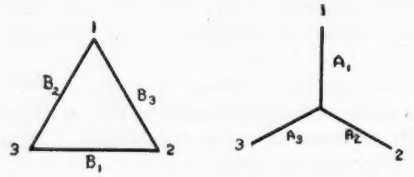
Solution of Wheatstone Bridge Network

THE TIME-WORN PROBLEM APPEARS ONCE MORE, THIS TIME, HOWEVER, WITH AN INTERESTING STAR-DELTA METHOD OF SOLUTION.

BY H. P. ST. CLAIR AND C. A. IMBURGIA

IN FIG. 1 is shown a network in the form of a wheatstone bridge, consisting of two triangles. A solution of this network is possible by means of simultaneous equations based on Kirchoff's Laws, such a solution, using determinants to solve the equations, having been illustrated on page 165 of January 15 issue of Power Plant Engineering.

To the mind of the writer by far the simplest solution of this network consists in changing one of the triangles to its equivalent star in accordance with the method described by R. D. Evans in the April, 1924, issue of the Electric Journal. The transformations from the triangle to equivalent star, and vice versa from star to equivalent triangle are as follows:



$$A_1 = \frac{B_2 \times B_3}{B_1 + B_2 + B_3} \qquad B_1 = \frac{A_1A_2 + A_1A_3 + A_2A_3}{A_1}$$

$$A_2 = \frac{B_1 \times B_3}{B_1 + B_2 + B_3} \qquad B_2 = \frac{A_1A_2 + A_1A_3 + A_2A_3}{A_2}$$

$$A_3 = \frac{B_1 \times B_2}{B_1 + B_2 + B_3} \qquad B_3 = \frac{A_1A_2 + A_1A_3 + A_2A_3}{A_3}$$

Applying the transformation to the triangle ADC of Fig. 1, we get the resultant network showing in Fig. 2. The three legs of the equivalent star, A_1, A_2, and A_3, are obtained as follows:

$$A_1 = \frac{5 \times 12}{42} = 1.42857 \text{ ohms}$$

$$A_2 = \frac{5 \times 25}{42} = 2.96719 \text{ ohms}$$

$$A_3 = \frac{25 \times 12}{42} = 7.14286 \text{ ohms}$$

The total resistance from A to B in Fig. 1, or its equivalent Fig. 2, is now easily obtained by simply

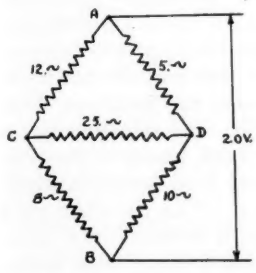


FIG. 1. FIVE RESISTANCES ARRANGED IN THE FORM OF A WHEATSTONE BRIDGE

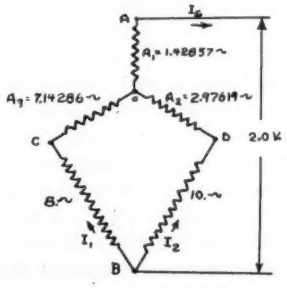


FIG. 2. RESULTANT NETWORK OBTAINED BY APPLYING THE TRANSFORMATION TO TRIANGLE ADC OF FIG. 1

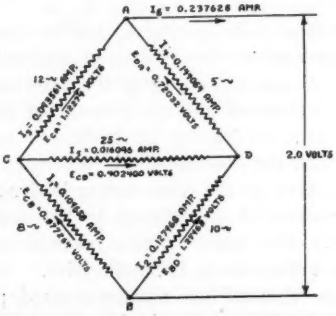


FIG. 3. CIRCUIT DIAGRAM SHOWING CURRENTS AND VOLTAGE DROPS IN EACH BRANCH

paralleling the two sides of Fig. 2, ODB and OCB, and adding to this the series resistance OA:

ODB = 12.97619 ohms
OCB = 15.14286 ohms
OBD in parallel with OCB = 6.9880 ohms
OA = 1.4286 ohms

8.4166 ohms
Total Resistance A to B

With 2.0 v. impressed from A to B, the total current I_6 will be

$$I_6 = \frac{2.0}{8.4166} = 0.237626 \text{ amp.}$$

Having found the total current, the currents in each branch I_1 and I_2 are easily obtained as follows:

The voltage across OA is:

$0.237626 \times 1.42857 = 0.339455$ v.

Then the voltage across ODB, which is the same as that across OCB is:

$2.0 - 0.339455 = 1.66054$ v.

Then

$$I_1 = \frac{1.66054}{15.14286} = 0.109658 \text{ amp.}$$

$$I_2 = \frac{1.66054}{12.97619} = 0.127968 \text{ amp.}$$

Check total $I_6 = 0.237626$ amp.

Having currents I_1 and I_2 we can obtain the voltages across BC and BD which are:

$E_{BC} = 8 \times 0.109658 = 0.877264$ v.
$E_{BD} = 10 \times 0.127968 = 1.27968$ v.

Going back to Fig. 1 we can now find the voltages across AC and AD respectively, which are:

$E_{AC} = 2.0 - 0.877264 = 1.122736$ v.
$E_{AD} = 2.0 - 1.27968 = 0.72032$ v.

Currents I_3 and I_4 are then

$$I_3 = \frac{1.122736}{12} = 0.093561 \text{ amp.}$$

$$I_4 = \frac{0.72032}{5} = 0.144064 \text{ amp.}$$

Check total current = 0.237625 amp.

Current I_5 will obviously be the difference between I_2 and I_4 or between I_1 and I_3, and having a direction such that the sum of the currents entering the point, say "D," will equal the sum of current leaving the point "D," the same thing being true for point "C."

Taking point "D" and assuming I_5 is in direction shown,

$I_2 + I_5 = I_4$
$I_5 = I_4 - I_2$
$I_5 = 0.144064 - 0.127968 = 0.016096$ amp.

As a final check, the voltage between any two points taken over any path between the points must be the same. Therefore, E_{DB} must equal $E_{BC} + E_{CD}$.

$E_{CD} = 0.016096 \times 25 = 0.402400$ v.
$E_{BC} = 0.877264$ v.
$E_{CD} = 0.402400$ v.

$E_{BC} + E_{CD} = 1.27966$ v.
$E_{DB} = 1.27968$ v. Check

THREE LARGE CENTRIFUGAL pumping units in the new sewage disposal plant in Brooklyn are arranged for automatic slowdown to prevent water hammer. This arrangement was designed by the General Electric Co. as follows: The pump motors are automatically started by a float switch and, when this closes, an oil circuit breaker is closed, thus throwing voltage on the primary of the motor. The motor then accelerates automatically until it reaches full speed.

When the pump motor is to be stopped the float switch opens and a contactor drops out, thus inserting resistance in the motor secondary and thereby slowing it down. At the same time, a definite time relay is energized, tripping after a predetermined time, thus opening the oil circuit breaker and shutting down the motor.

The three pumps are driven by 125-hp., 4150-v., slip ring G. E. motors. The Brooklyn plant is one of the first installations in the country where such provision is made.

Flames of Atomic Hydrogen

DR. IRVING LANGMUIR DESCRIBES THE NEW PROCESS OF WELDING WITH ATOMIC HYDROGEN BEFORE THE CHICAGO SECTION OF THE A. I. E. E.

AN EXTREMELY INTERESTING lecture on the subject of Atomic Hydrogen, by Dr. Irving Langmuir, drew a large attendance at the first of the year's meetings of the Chicago section of the A. I. E. E. and the Western Society of Engineers, on Sept. 27. Dr. Langmuir, assistant director of the research laboratory of the General Electric Co. at Schenectady, already famous for his work in the development of the gas-filled incandescent lamp and his brilliant researches in the field of electron engineering has, with his associates, brought about a development in electric and gas welding which promises to revolutionize the art of autogenous welding. This has been done through the use of atomic hydrogen, that is, ordinary hydrogen dissociated into free atoms.

Under ordinary conditions hydrogen exists only in the molecular form; that is, as HH or in groups of two atoms to form a molecule. When hydrogen is heated to above 2500 deg. C., however, Dr. Langmuir found that the hydrogen molecule is dissociated into free atoms. Upon cooling these free atoms of hydrogen recombine to form molecular hydrogen. It is in this final stage of the cycle that the phenomenon becomes of value in welding.

Naturally, to split the normal hydrogen molecule into two separate atoms, energy is required, in much the same manner that energy is required to decompose water H_2O into its constituents oxygen and hydrogen. When the atoms of atomic hydrogen recombine, however, to form molecular hydrogen, the energy which was added in the dissociation process is given up, just as the energy required to decompose water is liberated as the heat of combustion when hydrogen and oxygen are burned to form water.

In the welding process using atomic hydrogen developed at the General Electric Co. laboratory, a stream of molecular hydrogen is forced through an electric arc, causing it to dissociate into atomic hydrogen. A short distance (an inch or more) beyond the arc, the atoms of hydrogen recombine to form molecules of ordinary hydrogen, giving up at this point the heat of dissociation. The resulting temperatures obtained are far higher than anything heretofore obtained by any other process, in fact, the temperature is twice that obtained with the oxy-acetylene flame. Temperatures in the neighborhood of 4000 deg. K.* are produced.

In addition to the advantage of a much higher temperature than that obtained by other means, welding by the atomic hydrogen flame has other advantages. One which is extremely important is the extreme reducing action of atomic hydrogen. Any undesirable oxides that may be present in or on the metal to be welded are instantly reduced to the metal. Furthermore, no oxides are formed as is the case in ordinary processes where oxygen is present. The atomic hydrogen flame is entirely surrounded by molecular hydrogen, in other words in this process there is a flame within a flame; a flame of atomic hydrogen in process of recombination and a flame of molecular hydrogen burning in air. No oxygen can, therefore, get at the weld and no oxides form. This results in clean welds that are very ductile.

This in brief is the process as it has been developed and applied by the General Electric Co. and as described by Dr. Langmuir. What is of even greater interest than the description of the process itself is the scientific side—its inception in the researches of pure science.

In his lecture, Dr. Langmuir traced the development of the process back to the days when he studied with Nernst and was engaged in determining the heat dissipation from electrically heated filaments. Later on, in the research laboratory of the General Electric Co., while trying out the effect of introducing various gases into incandescent lamp bulbs, it was noticed that when the bulb was filled with hydrogen the heat loss from the tungsten wire by convection and conduction increased at a constant rate (the 1.9th power of the temperature) to a certain point and then increased much more rapidly. This was puzzling. With the other gases used, the heat loss increased at a constant rate up to the temperature limit of tungsten but not with hydrogen. With hydrogen when the temperature reached 1700 deg. K. the heat was dissipated much more rapidly than the 1.9th power, in fact, between 2600 deg. and 3400 deg., the heat carried away by hydrogen at atmospheric pressure increased with the 5.0th power of the temperature.

This abnormal behavior of hydrogen suggested that at high temperatures the hydrogen molecules are dissociated into atoms according to the relation $H_2 = 2H$ with the absorption of a large amount of energy. The enormous heat conductivity of hydrogen at high temperatures would thus be due to the absorption of energy from the hot wire by the dissociating hydrogen molecule and the liberation of this energy in the cooler gas at a distance from the wire by the recombination of the atoms which diffuse away from the wire.

While this view of the matter seemed probable yet there was a question as to whether it might not be due to the formation of an endothermic polymorphic form of hydrogen such as H_3 (corresponding to ozone, O_3). The dissociation theory, however, was soon confirmed by applying the law of mass action.

So it was from these experiments back in 1911 to 1913 which had absolutely nothing to do with welding or even with the production of atomic hydrogen that this important development grew. As Dr. Langmuir put it, at that time he was just curious to see what would happen when different gases were introduced in the bulb of an ordinary tungsten lamp.

Yet it is from such simple, apparently unrelated experiments that the most epoch-making discoveries are made. The development of the atomic hydrogen welding process proves it.

*This temperature is on the absolute (Kelvin) scale and can be converted to centigrade by subtracting 273 deg.

ACCORDING TO a recent announcement by the Department of Commerce, Washington, D. C., 104 stokers with a total capacity of 38,852 hp. were sold by 12 establishments during the month of August, 1926. Of these, 25 stokers with a rating of 3340 hp. were installed under fire tube boilers and 79 stokers with a rating of 35,512 hp. were installed under water tube boilers.

Delay in Delivery of Boiler Ground for Rejection by Buyer

By Leslie Childs

WHEN, and under what circumstances, the failure to deliver machinery on time will give the buyer the right to reject is a question with several angles. If the contract of sale clearly makes the time of delivery of the essence of the contract, delay may justify a rejection. On the other hand, if time is not of the essence of the contract, a delay in delivery may, or may not, justify rejection depending upon the particular facts involved.

Application of the foregoing rule is illustrated in a long line of decisions, among them being a prominent boiler manufacturer vs. a purchaser, a Missouri case reported in 282 S. W. 470. The facts and circumstances which culminated in this action being, in so far as material here, as follows.

Contract for Purchase of Boiler Entered Into

In this case the defendants contracted to purchase a boiler of the plaintiff for the sum of $2100. It was understood that the plaintiff was to manufacture the boiler at its place of business, and the contract provided, under the title, "Guaranties," as follows:

"Time of delivery.—Time of delivery to date from the receipt of full details of order and contingent upon delay caused by fire, strike, accident, late mill deliveries, or other hindrance beyond our control."

Contained in the original proposal, which was made a part of the contract, was the following:

' Shipment: Within 10 weeks."

Now, it appears, the contract started running on Sept. 13, that being the date of its acceptance by the plaintiff. Plaintiff was delayed in the work for more than 10 days by the failure of the mills to make delivery of plate. Manufacture of the boiler was begun, however, as soon as possible and completed on Nov. 30.

In the meantime, it appears, the defendants made inquiry in October as to when they could expect delivery. In reply to this the plaintiffs wrote that delivery would be made December 8, and to this the defendants made no objection.

Following the delivery on November 30, however, which was eight days over the time allowed by the strict letter of the contract, the defendants, on December 6, wired plaintiff as follows:

"Boiler not shipped within specified time of contract. Can buy same equipment for considerably less money."

Following this the parties entered into a dispute, which, to make a long story short, culminated in the instant action by the plaintiff for the price of the boiler. In defense against this, the defendants set up the delay in delivery. The trial of the cause, however, resulted in a judgment for plaintiff and, on appeal, the higher court in reviewing the record, in part, said:

The Record Reviewed

"The whole contention goes to the one question as to whether the court properly held that time was not of the essence of contract, and that delivery was made within a reasonable time. The contract was not to become binding until it was signed by plaintiff's executive officer, which was done September 13, 1920. While under the heading of 'Proposal' it was stated that shipment was to be made 'within ten weeks,' we must consider the other provisions of the contract which provided for certain delays. * * *

"There was more than a ten-day delay in the delivery of this plate by the mills, * * * and as soon as the plates were received the work was begun and proceeded as rapidly as possible until the boiler was completed.

"When the defendants inquired as to when the shipment was to be made, they were told by letter that same could not be made before December 8. Plaintiff, however, did succeed in making delivery by November 30, 1920. The defendants made no reply to this notification and made no effort to rescind the contract until after the boiler had been shipped.

If we compute the time of ten weeks from September 13, it would be November 22, when the ten weeks were up; then in so far as September 13 is concerned, the delivery was eight days beyond the ten-week period. If allowance is made for the ten-day unavoidable delay because of mill deliveries, then the delivery was made two days before the ten weeks had expired. * * *"

Following the above review of the record, the court proceeded to reason on the question of whether or not, under the facts as they have been stated, time was of the essence of this contract which would prevent a recovery by the plaintiff because of the delay in delivery. In this connection the court, among other things, said:

What the Court Decided

"In considering this case, it will not do to treat this case under the peculiar rule of sale from merchant to merchant for resale. Time, to be the essence of a contract, must be so intended by the parties. * * *

"In Lane v. Nunn, * * * 211 Mo. App. 280, this court said:

' 'Where a contract has been mutually and fairly entered into by both parties and time is not expressly made the essence of the contract and neither party has expressly repudiated it, * * * one party cannot evade its obligations on the ground of delay of the other, unless he shows damage to himself by such delay, or such an unreasonable or intentional and willful delay as will evince an intention on the part of the delaying party to treat the contract as at an end. * * *'

"We think the trial court correctly held that time was not of the essence of this contract, and that it rightly decided that there was no breach of this contract by plaintiff so as to justify the defendants in repudiating it and refusing to take the boiler when delivered, under the facts and circumstances of this case. Judgment affirmed.

This case is one of force and value on the question decided, and constitutes an apt illustration of when and under what circumstances time will be considered of the essence of a contract. In view of the facts involved, the holding and reasoning of the court may well be had in mind by buyers and sellers of machinery in general when contracts of this kind are being entered into.

Specifications for Hydraulic Turbines

UNIFORM PRACTICE WITH REGARD TO SPECIFICATIONS IS NEEDED TO ELIMINATE MISUNDERSTANDINGS. BY JOHN S. CARPENTER

EXPERIENCE of over 17 yr. in reading and comparing hydraulic turbine specifications reveals the greatest variety of thought and practice in this direction. The length of the specification runs all the way from 200 words to the length of a "best seller"; from the barest description of the physical conditions to the most careful specification of the stresses in minor parts. A case comes to mind of a specification for one of the world's largest hydraulic turbine units, written by a noted hydraulic engineer, in which the whole subject was covered on half of a standard size letter sheet. The other extreme was a specification for a 25-hp. water turbine for a small town, the length of which was 45 pages of legal size paper, typed single space.

Naturally, this question suggests itself: What did the first named risk by its brevity and what did the second gain by its great length? The first case was that of a large power corporation having a complete staff of unusually capable engineers. Any bidder for equipment of such dimensions knew without a second thought that he would have to show a complete design and all important details; he would come prepared to show tests, private laboratory, at Holyoke, and tests in place on the job. He knew that every detail of importance would be subject to keen scrutiny and analysis. Aside from the technical qualifications, the financial condition of the builder and his ability to carry out the contract, if awarded, would be of great importance. In commenting on the second case, it is probably a fact that the town paid more for the turbine unit so specified than if a much more modest specification had been issued.

In any event, there should be some accepted form for a request for bids and a specification. For the benefit of those who wish to make closer definition of their requirements, let there be a rather complete model which will state the purchaser's demands for each important part and feature. The requirements of the briefer specification will be met by a shorter form, which will take due time to specify leading details. As might be naturally expected, there is a tendency to skim lightly over a very long and awkwardly written document, while a clear and crisp specification is more readily analyzed and borne in mind while preparing the bid.

If the special conditions attending a particular development require much precision in definition, the end sought will be greatly furthered by breaking up the body of the specification into sections that focus directly on the subject under the sub-heading, and only referring to other sections when absolutely required. In this way a specification reader can take a single sheet of paper and list important items in short notes and pass them along for incorporation into the designs. It is rather conducive to mental rupture to get hold of a rush proposal covered by a lengthy specification containing modifying clauses for the same detail in widely separated portions.

As a suggestion the following is a skeleton form of item arrangement which can be expanded to suit the ideas of the engineer in charge.

In the first paragraph of the specification, the full name of the buyer should be given, the location of offices and works, together with the relation of the project to its surroundings; such as nearby cities, etc., and whatever railroad facilities there are. A concise statement of the character of the power, its use and special governing requirements, if any, and probable interconnection with other power plants, should now be given. This data is as important to the generator manufacturer as it is to the hydraulic turbine builder, having a material bearing on the governing qualities of the proposed plant.

Specify the physical conditions over which the turbine builder has no control; such as range of head, length of pipe line, location of surge tanks if any and what size, setting of the turbine, special restrictions as to draft tube width or height, range of head and tail water levels and variations in flow due to seasonal changes.

Now is the time to specify the power desired; whether this is to be at a so-called "regulating point," full gate opening power, or full rated load power with a small excess. Specify at which head this power is desired if there is a head variation and define the tailrace condition for this head and load. The purchaser and his engineer must appreciate that turbines cannot be designed for exactly so much power under such and such a head and then have them come out on the dot to that power. It must be realized that there should be a tolerance or an excess reserve to cover contingencies of fabrication; such as shifting of cores, mold swell and the like. In many cases the builder finds that there is some inherent condition or combination of abnormal draft tube conditions with other features that make it doubly advisable to provide a small additional reserve. By all means, define the conditions for which maximum efficiency is desired; at what head; at what power, thereby making it possible for the turbine builder to tender on an intelligent basis and then all bids will be based on somewhere near a common basis.

Defining the desired conditions necessarily raises the question of speed. There are two courses open to the purchaser; first, let the turbine builders suggest speeds in a preliminary way before final specifications are sent out; second, your engineer can study the well known experience curves and having data on previous plants known to be successful, he selects the speed and the turbine builders conform. The first is probably the most satisfactory, as the turbine builder knows what he has to guarantee and the consequences that follow the selection of too high a speed. A study of experience curves, however, may not be time wasted in any event. These experience curves are usually plotted with specific speed as the horizontal scale and head as the vertical scale. From much experience, it has been found that the majority of successful plants will lie below a curve that looks somewhat like the expansion line of a steam engine indicator diagram. Plants that have had trouble from extensive pitting and runners going to pieces will usually be found above such a curve although there is

what might be called a twilight zone. Such curves can be found in Marks' Handbook and also Kent's Handbook, therefore they need not be reproduced here. In the last few years, there has been some progress in the field of low head turbines so that higher speeds can be used in this work to cut down generator costs, but due caution should be observed in medium and high head plants, but no marked departures made without rather conclusive proofs.

We will assume that exact quantities have been given so every bidder will know just what is wanted. The question of efficiency guarantees now arises. The turbine builder is wondering, at this point, if high efficiency is desired, or whether efficiency is not of prime importance. Further, he is wondering if high part gate efficiency is wanted. Buying hydraulic turbines is in some ways like buying a watch. You can go down town and get a watch that will keep fair time and wear 5 or 6 yr. for a five dollar bill. You have bought a watch, but there are watches and watches. If you want a watch that will keep railroad time and do it for twenty years as a useful life before extensive repairs are needed you will pay ten times the price of the first watch. If you want a turbine that will squeeze the last foot-pound possible from water, and do it with continued economy for years, it will cost more than a mere "turbine" although not anything like twice as much. A hydraulic turbine for high efficiency requires more care in design and manufacture and naturally must be paid for; the patterns cost more and often are more or less special.

Some engineers will define the value of an extra per cent in efficiency. For example, one per cent extra efficiency means one per cent extra power. This power for a year is worth a certain figure. There are different methods of arriving at the final figure and it appears to be variously considered. Many specifications for the Government state that 1 per cent efficiency is worth $1000 as concerns a method of crediting a high efficiency turbine bid and penalizing a low efficiency turbine bid. Values as high as $4000 have been noted in high class installations.

At this point, some engineers now insert the patent clause. This is to the effect that the purchaser shall be saved harmless and free of all costs due to alleged patent infringements and losses due to injunctions and that the builder shall assume any suits instituted against the purchaser and defend them at his own cost as if his own. Many proposals, especially for city and government work, require a bond for faithful performance.

Gate Valve or Butterfly Valve

Depending on what is selected, a gate or a butterfly valve, this should now be specified. One usually finds a clause requiring that the leakage under full working head shall not exceed 5 gal. per min.

Spiral Casing for the Turbine

Next in order is the turbine casing, usually of the spiral type. It is usually cheaper to buy a plate steel spiral casing than to build wooden formwork and cast the casing in concrete around it, unless the casings are of tremendous size. The steel plate casing of circular cross section is good for at least 300 ft. head and for the best work the completed casing should be tested under a pressure of at least 60 per cent more than the maximum expected. Under these conditions the stress in the steel plate sections should not be greater than about 15,000 lb. per sq. in. or there is the liability to stretch the rivets and induce leakage. If the speed ring section is made of cast iron, the allowable stress in the stay vanes should not exceed 2200 or 2300 lb. per sq. in. at the test pressure, while for cast steel 8000 to 9000 lb. per sq. in. should not be exceeded.

Gate Stems and Breaking Links

Good practice in the design of gate stems and gate pivots in general provides that two gates shall take the entire governor effort and that the stress in the gate stems so figured shall not exceed 35,000 lb. per sq. in. This stress is the elastic limit for usual materials. Some engineers prefer the use of breaking links; so that should a log or other obstruction get between two gates and become wedged there, the gate links will break before the gates do.

Runners

If the water contains much grit or sand, wearing rings put on the crown and band of the runner will materially lengthen their useful life. These rings are renewable, usually made in one piece, although they can be made in sections and attached with screws. They are usually steel and can be hardened somewhat if desired. To do the job right, the stationary part of the running joints should likewise be lined so that a renewal finds the running joints equal to new. When renewable wearing rings are not used, any sand will tend to cut the joint out and the leakage that can get through in some jobs is often as much as 15 per cent of the full load water quantity. This corresponds to a direct power and efficiency loss of as much. Special forms of labyrinth joints will reduce the leakage down to one-half of one per cent, if required, but are somewhat costly. Normal leakage values run about 2 to 4 per cent, without costly designs, depending on the clearance allowed.

Runners should always have the vanes rubbed down smooth and then painted several coats of red lead, excepting bronze runners which need no paint. All bumps and hollows should be removed by chipping and filling. Sharpening of the entrance and discharge edges will help the efficiency and power and the builder will do it as a rule for his own protection. But in any event, sharpening should only be done on the leading side of the bucket, in order of rotation, and not on the trailing side.

The Draft Tube

It will usually be found that each builder has some tested out draft design that he can fit into the space available and which will be superior to any designed for the occasion by those not in a position to make extensive tests. It should be noted, in passing, that all elbow tubes that may look alike, are not of necessarily equal quality. Elbow tubes have been developed that come within 1 per cent of the turbine efficiency secured with straight tapered tubes, these last being the best design if there is not too much excavation necessary.

It is necessary to make a test if the turbine builder's guarantees are to be checked. If the turbine builder

knows that no test will be made, there is the tendency to make high guarantees, although this is not to be looked for when dealing with builders of high repute. Current meter tests are all that can be made in some locations and should always be taken with reservations of at least 2 per cent plus or minus, in final results, of absolute values.

Weir tests, where the weir is of standard form, are regarded as accurate within 1 per cent if careful work is done. The salt methods and the Gibson method are very highly regarded, but require special apparatus and attendants of experience in their special problems.

Resume

If this article will assist in helping write better and more explicit specifications a good service will be done all around. Much is to be gained by reducing our practice to a more uniform basis which will eliminate the chances of misunderstanding and the receiving of bids that are not what the purchaser nor his engineers want.

Air Conditioning and Cooling in Hudson Stores

Clean, Fresh Air of Proper Temperature and Humidity is Best Atmosphere for Department Store. By D. C. Lindsay*

EXPERIENCE has taught the operators of department stores that the temperature and humidity of the atmosphere within the store reacts directly upon the volume of business.

During the holiday rushes and during the summer months, in department stores which have taken no steps to control air conditions, the condition of the atmosphere frequently becomes almost intolerable. This reacts upon the courtesy and efficiency of the store attendants and likewise upon the patience of the customers. Customers remain to make more purchases if they are comfortable and come to the store more frequently when they know that they will not become exhausted by a stagnant, overheated atmosphere. The store attendants are more efficient, more cheerful and are less subject to colds and other ailments which keep them from work, if the atmosphere within the store is kept clean and fresh and at a suitable condition of temperature and humidity.

These are facts which appealed to the economic reasoning of the officials of the J. L. Hudson Stores in Detroit. Through a thorough investigation of the application of air conditioning engineering in many industrial fields and in public buildings such as theaters and hotel dining rooms, they were convinced that the same results could be accomplished within their store. They were sure that if such results were accomplished, an investment of considerable size for this purpose would be justified.

Contracts were let to the Carrier Engineering Corporation to provide a system capable of cooling one basement and the first floor of their older building and two basements, the first floor and mezzanine of their new building which was occupied for business in 1925. The system has now been in operation since the autumn of 1925 and has given every indication that a properly engineered and installed air conditioning system is a decided asset to a department store of this magnitude.

The system was designed to control the air conditions on the floors mentioned because it is a generally accepted fact that within a department store, the volume of sales per unit space within the basements and first floor is

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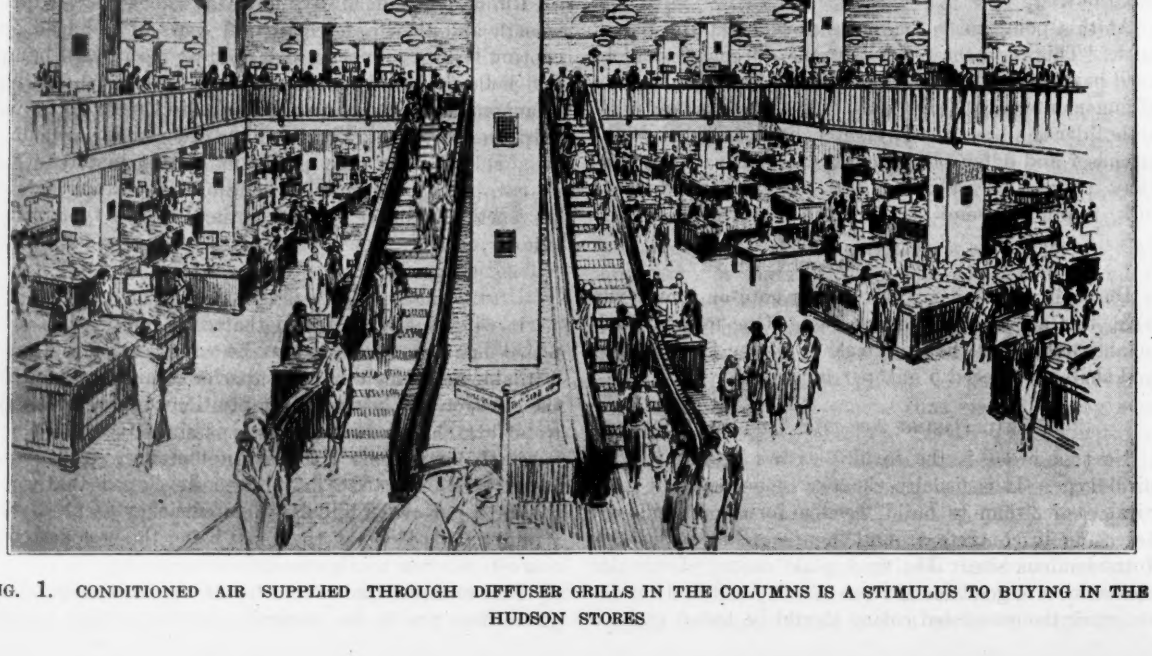


FIG. 1. CONDITIONED AIR SUPPLIED THROUGH DIFFUSER GRILLS IN THE COLUMNS IS A STIMULUS TO BUYING IN THE HUDSON STORES

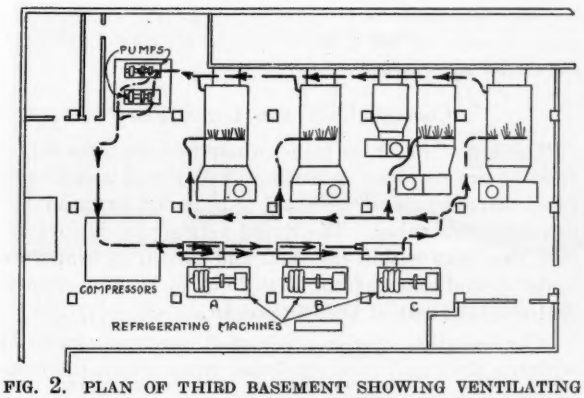


FIG. 2. PLAN OF THIRD BASEMENT SHOWING VENTILATING AND CONDITIONING EQUIPMENT

from three to four times greater than in any other portion of the building. To engineers, the interesting phase of this story is, of course, the mechanical equipment and how the results are accomplished. The system consists of four sets of spray chambers and fans designed to supply to the various departments, a total of 200,000 cu. ft. of air per minute. The spray chambers serve at all times as air washers.

During winter, the water within the spray chamber is tempered sufficiently to raise the dewpoint of the air to approximately 50 deg., thus serving as a humidifier.

During the summer, the water supplied to the spray chambers is cooled by means of a unique refrigeration system, which will be subsequently described, so that the dewpoint is held down to a temperature of approximately 50 deg., thus serving as a dehumidifier. The dewpoint of outdoor air during the summer time is frequently 60 deg. or above so dehumidification during the summer season frequently demands a rather large refrigeration capacity.

Starting at the fresh air intake on the 17th floor of the building are two large centrifugal fans, each handling approximately 50,000 cu. ft. of air per minute. These fans blow the air down to the conditioning equipment located in the third basement. In the winter time the air is heated on the 17th floor before being blown down by these fans.

In the third basement there are four main air conditioning equipments, each taking care of a certain section of the store. Referring to the attached sketch, the four units referred to are Nos. 1, 2, 4, 5.

Unit No. 3 on the sketch is a small air washing unit used to supply air to the machine room and stock room in the third basement.

Air filters are also used in connection with the system so that at any time that it is desirable to operate without the use of the sprays, a clean air supply is assured.

Air is carried to the various departments through metal ducts and is admitted to the rooms through diffuser grills located on the side walls and in the supporting columns. The air is returned to be rewashed and reconditioned through openings located near the floor line throughout the store. A constant dilution of fresh air amounting to about 25 per cent of the total volume delivered is taken in.

During the winter season the air is humidified and

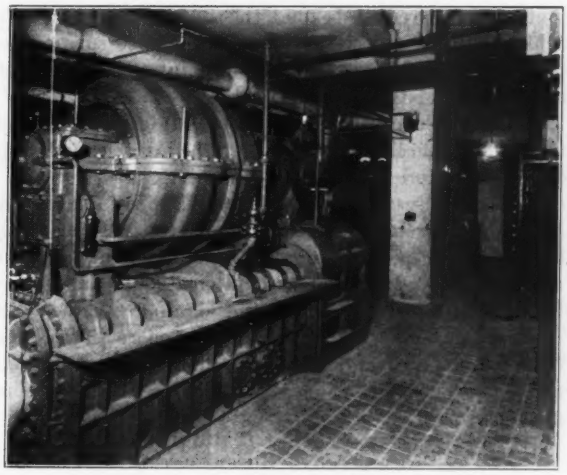


FIG. 3. CONDENSER FORMS BASE OF CENTRIFUGAL COMPRESSOR FOR 200-T. REFRIGERATOR UNIT

tempered to the temperature found to produce maximum physical comfort. All heating is done by the heaters located within the air supply ducts. No direct radiation is required within the store. As the store becomes congested, little or no heat is required even in the coolest weather. In fact, it has even been found necessary during the Christmas rush to resort to the use of the refrigeration system.

The result of automatic regulation of temperature and humidity and of the indirect heating of the building is invariably an appreciable saving in fuel. The circulation of air conditioned enroute to the room insures even temperatures at all points and avoids local hot and cold spots such as result when direct radiation is used and convection currents are the sole means of air circulation.

Summer Operation

To maintain pleasant and comfortable air conditions during the winter, is of greater importance than has been recognized. Of even greater importance, however, so far as the reaction upon business and immediate physical comfort is concerned, are the conditions which essentially the same equipment provides during the summer season. At a time when humidity and temperature are both excessive, when people are irritable and anxious to get home, business in every line seems to "flop." No one can doubt the drawing power of a store in which the temperature and humidity has the inviting restful effect of an ideal spring day. Customers come and stay to purchase and they return. Such are the facts at Hudson Stores.

Within the spray chambers, the cold refrigerated water is sprayed. The water cools the air sufficiently to cause the condensation of an appreciable amount of the moisture from the entering air. This condensation, *this dehumidification,* is the important thing. It is possible to cool the air with the ordinary supply of city water or, to recirculate the water within the spray chamber, thus obtaining a saturation temperature approximately at the wet bulb of the entering air. This is the manner of operation of the ordinary air washer. In this way, the air is cooled but its absolute humidity, its moisture

content, is increased beyond the state of comfort. To dehumidify, it is necessary that the temperature of the spray water be lower than the dewpoint or condensation temperature of the entering air.

Humidity controls comfort. It is interesting to note from the researches conducted by the American Society of Heating and Ventilating Engineers, that air at 75 deg. F. and saturated is no more comfortable to the human body than air at 95 deg F. (20 deg. warmer) having but 10 per cent of its possible moisture content.

Conditions stipulated and automatically maintained in Hudson Stores, regardless of outdoor weather conditions, are temperatures varying not more than 3 deg. from 75 deg. F. and a relative humidity of approximately 55 per cent. This is found to be ideal for summer comfort.

Centrifugal Refrigeration

Air conditioning, including dehumidification, passed out of the experimental stages long ago and has seen

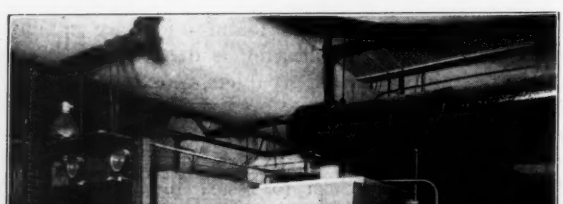


FIG. 4. COOLING CHAMBERS ARE CORK INSULATED AND UNDER AUTOMATIC CONTROL MAINTAIN TEMPERATURES WITHIN 3 DEG.

many instances of successful application within various industries. One of the principal drawbacks in the application of dehumidifying equipment within public buildings had been in the characteristics of the refrigeration machines and refrigerants which were available.

In the Hudson Stores, the Carrier centrifugal refrigeration system is used which is comprised of three major pieces of equipment operating as a compact unit. These are the evaporator or cooling unit, the centrifugal compressor and the condenser.

Compression is accomplished by a simple multi-stage centrifugal unit similar in construction to the familiar forms of centrifugal compressors used for air and not unlike a centrifugal pump. The only contact of moving parts in the whole system is at the main shaft bearings. The compressor operates at speeds in the neighborhood of 3600 r.p.m. It may be driven by a directly connected squirrel cage a.c. motor which has been successfully developed for this purpose or, it may be driven through gears by motors of lower speed or, it may be driven by almost any form of directly connected steam turbine.

The three units in Hudson Stores having an approximate capacity of 200 t. are driven by air cooled, directly connected a.c. motors.

Cooling Unit and Condenser

Cooling of water, or brine, where temperatures below freezing are required, is accomplished within a shell and tube compartment. The liquid to be cooled is circulated through brass tubes. The liquid refrigerant is sprayed over the tubes within the shell and caused to evaporate under a condition of from 25 to 28 in. of vacuum created on the intake side of the compressor.

Condensation of the refrigerant vapor is produced within a shell and tube condenser upon which the compressor rests as a base.

The characteristics of the refrigerant are such that condensing water at 90 deg. F. will produce condensation at an absolute pressure of about 8 lb. This means, under extreme conditions, a pressure differential of 7 lb. between the intake and discharge side of the compressor. The ordinary ratio of compression is usually less than five.

It is to be noted that the entire system operates under conditions of vacuum relative to the atmosphere and that outward leaks are impossible.

From the condenser, the liquid refrigerant returns to the evaporator or cooler under its own head. This completes the cycle.

New Refrigerant Used

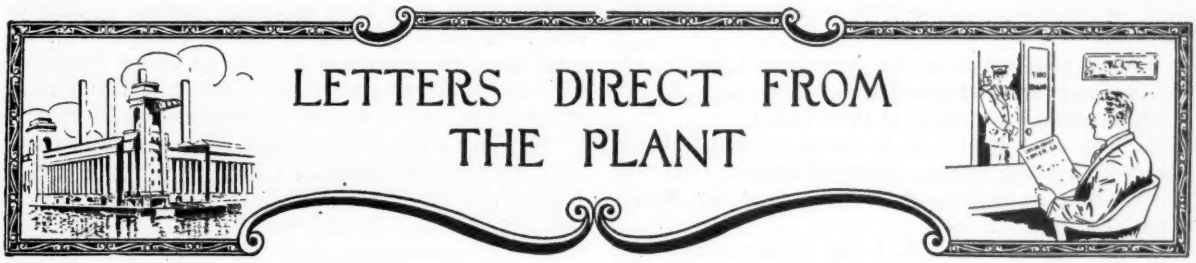
Dichloroethylene is the refrigerant used, commercially known as dielene. This is a completely stable liquid at all atmospheric pressures and temperatures and is entirely safe to be conveyed in open containers. It is obtainable in an absolutely non-combustible form. The ordinary form of the liquid is only slightly combustible and its vapor is of sufficient density to blanket it completely and extinguish a flaming surface of the liquid. The specific gravity of the liquid is higher than that of water. The density of the vapor is approximately 3½ times greater than that of air.

As already stated, the entire system operates under conditions of vacuum relative to the atmosphere which precludes any possibilities of outward leaks. If, however, any circumstance should cause the refrigerant to be liberated from the machine, its low diffusion characteristics are such that no hazards whatever would be offered to occupants of a building.

Each of the three units located in the third basement of the new Hudson Stores building occupies a floor space of approximately 150 sq. ft. This includes control boards, starting apparatus and working room. The accompanying photographs will serve to illustrate the extreme compactness of the units.

Automatic Control

Notable too, are the automatic temperature and load controls in this system. Control is effected directly by thermostatically controlling the condenser water supply, by which means it is possible to maintain a constant evaporator or cooling compartment temperature with a varying load. Wide variations in load are also subject to control by variation in the compressor speed.



Points to Be Observed During Boiler Inspection

PRELIMINARY TO a boiler inspection, the boiler, drums, tubes, headers, mud drum, furnace and ashpit should all be thoroughly cleaned to facilitate a careful inspection. In the case of return tubular boilers, blisters or thin places may occur, the presence of which may be ascertained by going over the plates with a hammer. When blisters are discovered the plates should be repaired or replaced. Repairing a blister consists in cutting out the blistered space and riveting a hard patch over the hole on the inside of the boiler, if possible, to avoid the formation of a pocket wherein scale or sediment may collect. All seams heads and tube ends should be examined for leaks, cracks, corrosion, pitting and grooving, detection of the latter possibly requiring the use of a magnifying glass. Uniform corrosion is a wasting away of the plates and its depth can be determined only by drilling through the plate and then plugging the hole Pitting is due to a local chemical action and is readily perceived. Grooving is usually due to a buckling of the plates when under pressure and frequently to the careless use of the sharp calking tool. Seam leaks are generally caused by overheating and demand careful examination as there may be cracks under the rivet heads. If such cracks are discovered the seam should be cut out and a patch riveted on. Loose rivets should be carefully looked for and if found, should be cut out and replaced. Pockets, or bulging, and burns should be looked for in the firebox on plates or tubes. Pockets in horizontal return tubular boilers are not necessarily dangerous but if there are indications of their increasing they should be heated and forced back into place or cut out and a patch put on.

Burns are due to low water, the presence of scale or to the continuous action of flames formed on account of air leaking through the brick setting. The condition of all stays, braces and their fastenings should be examined and the defective ones replaced. All exterior surfaces of the boiler should be carefully examined for signs of corrosion, which is likely to set in on account of dampness, exposure to weather or other corroding influences, leakage, etc., and may be serious. The boiler should be set so that joints and seams are accessible for inspection, and should have as little brickwork in contact with them as possible. The brickwork should be in good condition and should be free from airholes through which the air may filter in through the setting. The muddrum and its connections are liable to corrosion, pitting and grooving and should be examined as carefully as the boiler.

Examination should be made of all valves on the boiler. The gage cocks and also the gage glass should be tried to make sure that they are not choked. The steam gage should be taken down, tested and corrected if necessary. The gage pointer should move freely. The safety valve should be lifted from its seat so as to make sure that it will operate and not stick. All indicating and recording apparatus should be inspected and cleaned if necessary.

Los Angeles, Calif. C. C. BROWN.

Steam Pipe Sizes Easily Determined

EVERY engineer has his own ideas of the proper practical size steam pipe to use, dependent upon the correlation of velocity and pressure. The determination, however, requires calculation, which can be simplified by using constants for pipe size and pressure. A convenient method, with the constants involved, is as follows:

TABLE I
PIPE FACTOR P

Size	P
1	0.33
1.5	0.74
2	1.31
2.5	2.05
3	2.95
4	5.23
5	8.20
6	11.8
8	21.0
10	32.7
12	47.2
14	66.1
16	83.6
20	131
24	189
30	294
36	425
42	578
48	755
54	955
60	1180
72	1700
84	2310

TABLE II
STEAM FACTOR S

Press	S
0.25	1237
0.50	642
0.75	437
1	333
1.5	226
2	173
3	118
4	90.5
5	73.3
6	61.9
8	47.3
10	38.4
12	32.4
15	26.3
18	22.2
21	19.2
25	16.3
30	13.7
35	11.9
40	10.5
50	8.51
60	7.17
75	5.81
100	4.43
125	3.58
150	3.01
200	2.29
250	1.85
300	1.55
400	1.17
500	.93
600	.76

$P = L \times S \div V$ where

P = A pipe factor, corresponding to the pipe size as given in Table I.

L = Pounds of steam an hour

S = Steam factor, corresponding to the pressure as given in Table II.

V = Velocity in feet per minute.

As a sample calculation for 300,000 lb. steam an hr. at 400 lb. absolute pressure and at velocity 8000 ft. a min., S is 1.17.

$P = 300{,}000 \times 1.17 \div 8000 = 43.9$, indicating 12-in. pipe.

Results obtained with this formula and factors are well within practical requirements but, for accurate calculation, attention is called to these facts:

1. The pipe factor, P, is based on actual inside diameter, I. D., in inches. This will require correction for actual pipe weight or thickness used for specific conditions.

2. The steam factor, S, is the specific volume for dry and saturated steam. For each 6 deg. superheat, increase S 1 per cent. For each 1 per cent moisture in the steam, decrease S 1 per cent.

C. M. HARDIN*

Steam Coils Balk and the Cure

FIGURE 1 shows a steam coil that never would function properly. A lot of other coils, made up exactly the same, have never given a minute's bother but this particular one always would be cold on the three bottom pipes,

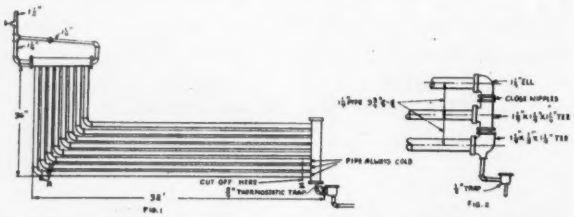


FIG. 1. WITH ORIGINAL CONNECTIONS, THREE BOTTOM PIPES WERE COLD

FIG. 2. THIS SEPARATE TRAP CLEARED THE COIL

clear back to the elbows at A. Larger traps in tandem and about everything the steam fitter could think of were tried but nothing seemed to do any good. Last winter the coil froze and was used no more that season.

This summer I got busy and tried a stunt of my own; so far everything has been lovely. The three lower pipes were cut off 4 in. shorter at X, and the openings in the branch tee plugged. The three pipes were then connected at X as shown in Fig. 2. No change was made in the connections on the supply end.

We have coils twice as long, with ½-in. trap taking care of the condensate, which have never given trouble. With a ¾-in. trap, which is supposed to take care of more than twice as much radiation as the ½-in. trap, I never could figure why it would not work.

Ash Pile Indications

ONE OF my best lessons learned in the past year was taught by an old time boiler man who was in charge of a neat plant. "Watch the ash pile."

Discussing boiler houses we had seen, I was enlarging on the many I had visited with large boilers, big stokers, automatic control, recording instruments, dandy coal handling, painted boiler rooms, superheat and other wonders of modern plants. When I was through, he asked, "Did you go look at their ash piles?"

I confessed that I hadn't thought it important but I realized at once what a story the ash pile can tell. Then I recalled some plants where I had seen, but not examined, the ash piles and felt that things might not be so rosy there as I had thought.

One plant, with large underfeed stokers, pushing in coal for all they were worth, had an ash spill with big piles along the track and I could remember quantities of coked and unburned coal showing. Maybe those stokers were feeding too fast without enough air supply.

In another plant, having chain grates, I could recall an ash pile which resembled a coal pile in color. I had looked into the last inspection door where clinker dropped into the pit and thought the stoker had run away and was dumping over good coal. The operator insisted that it was their method of operation and the ash pile bore him out, yet the boiler plant looked good and seemed efficient. I thought of the old platitude about beauty and skin thickness and concluded that "saving the surface and you save all" doesn't apply to power plant operation. You have to get below the surface to find the real facts.

We went back to look at my friend's ash pile. His plant was mostly hand fired but the ash was fine and clean. His ash hadn't been analyzed for years but I doubt if there was over 10 per cent combustible in it. No large clinkers with coke centers, no lumps of raw coal, and the pile seemed small.

Yes, I learned the lesson. To get the real results about furnace operation, you must study the ash pile. It's an encyclopedia on the subject. It isn't the whole story but it tells a lot and no plant story is complete without the tale the ash pile tells. Now, when I visit a boiler plant, I consult the ash pile first.

Pittsburgh, Pa. C. W. STEARNS.

Graphite for Heavy Pipe Joints

GRAPHITE is the best "dope" to use for heavy pipe joints, especially where they are exposed to great heat. A few days ago I watched some workers cut out a 3-in. blowoff pipe which was of extra heavy make. It was set up so hard in the boiler flange that even by the use of a 4-ft. chain wrench, the workers moved it with great difficulty. They had the new pipe cut and ready to install by the time they got the old one cut out.

Before installing the new pipe, the thread was given a good coating with a red lead and boiled oil mixture. I suggested to the engineer that graphite be used instead of red lead. He looked at me as if he felt sorry for my ignorance and explained that red lead would fill up the irregular places in the threads much better than would graphite. He did not realize that a properly cut and well lubricated thread is just about as tight without any red lead as it is with it.

Besides, being a high grade pipe thread lubricant, when oil is used with it as a binder, graphite also has the property of not burning and of acting as a cement. A large number of engineers swear by flake graphite for use on pipe threads; my preference is for pulverized graphite. I have seen pipe which were somewhat difficult to unscrew, after years of service, where flake graphite had been used; but I have never found joints as firmly set where the pulverized graphite had been used.

Where it is definitely known that the pipe joints will never need separation during its life, it is, of course, all right to use red or white lead.

Toronto, Canada. J. E. NOBLE.

*With Ernest E. Lee Co., Chicago, Ill.

Tape End Holder

When using the measuring tape alone, a good tape spike is your best partner. The sketch and photo show a practical one made from an old Ford engine valve. A slanting notch is cut in the shank with a hack saw. This keeps the eye of the line from dropping down and is close enough to center. Its shape enables it to be easily forced into ground, wood, or anything else that will yield to a point.

CONVENIENT TOOL FROM A DEAD FORD

If you cannot procure an old valve from a Ford—tell us quickly where you have fled. A valve from a Fordson will give a longer shank, if you prefer it.

F. W. Bentley, Jr.

High Carbon Dioxide in Flue Gas

Nowhere in printed matter has the writer been able to discover matter covering abnormal carbon dioxide, but eight instances have come to his attention in which readings of upward of 21 per cent were taken during commercial boiler furnace tests. In each instance the tests were made by a competent Orsat operator and under conditions which left no doubt that the test actually represented the amount of carbon dioxide as found. As a consequence of the opinion expressed that there was faulty Orsat operation, observations and tests were made to determine, if possible, the reason for the high reading.

Modern text books state that hydrogen in wood fuel is combined with oxygen, disregarding the fact that wood fuel has a heat value of about 9200 B.t.u. per pound dry, while the carbon in the fuel can have at the maximum a heat value of only 7270 B.t.u. Were it not for the oxygen in the wood fuel, this would figure to have a maximum normal carbon dioxide value of about 16 per cent. With the oxygen present, however, the figured maximum carbon dioxide, with no excess of air, is about 20.2 per cent. The wood fuel under test had less than ½ per cent of ash with a trace of carbonate in the ash due to shells and other organic matter. When taking readings, a caustic soluble solution was used with five times the capacity required to dissolve out the carbon dioxide and absorptions were repeated until a constant reading was obtained. Introducing a fresh solution of caustic would take no more additional gas, after the first solution had been used to a constant reading.

In making the test, a large Pyrex retort was used to permit absolute control of all gases entering or leaving the combustion chamber, this retort being placed in an electric oven to simulate hot refractory walls because the thermal capacity of thin glass walls is small. The retort was almost entirely filled with fuel in the shape of coarse sawdust. Temperature records were taken inside the retort as well as inside the oven and gases were taken through two scrubbing bottles before being tested in the Orsat. These bottles were charged with saturated liquid so that the moisture, tar, creosote, and other impurities were condensed in them, leaving dry gases for the Orsat test, in which readings were taken at a constant gas temperature of 70 deg. F.

Ultimate analysis of the wood fuel can be taken as follows: Carbon, 50.31 per cent; hydrogen, 6.2 per cent; oxygen, 43.08 per cent; ash, 0.37 per cent. Of these carbon and a large part of the hydrogen and oxygen are available for combustion as the heat value of the fuel indicates that about 17 per cent of the oxygen is available. Application of heat even at a temperature as low as 250 deg. causes gases to be given off and at 480 deg. carbon dioxide will be formed in considerable quantities. Under these conditions it is quite conceivable and even probable that the oxygen has a greater affinity for the carbon than for the hydrogen and carbon monoxide, hence carbon dioxide will be formed in the presence of either free oxygen or hydrocarbon.

One set of results from these tests read as follows: Carbon dioxide, 53 per cent; carbon monoxide, 41 per cent; oxygen, 0.4 per cent; heavy hydrocarbons, 2.5 per cent; light hydrocarbons and undetermined, 3.1 per cent. It appears evident that wood in the presence of heat and with absence of sufficient air, will break up somewhat in that way. Carbon monoxide, hydrogen and hydrocarbons will be burned to carbon dioxide and water as in normal furnace combustion when there is sufficient air but, when there is a low percentage of excess air, the reaction as shown in the test above will take place and, under special conditions, Orsat readings of upward of 21 per cent carbon dioxide may be obtained.

Powell River, B. C. M. S. Gerend.

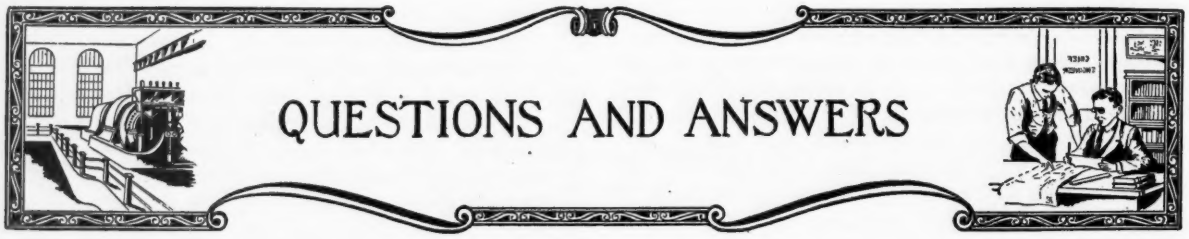
Soot Blowers, Use 'Em

Once an engineer, who was operating a battery of six B. & W. boilers, told me that the only time he removed the soot was when he went into the combustion chamber to inspect the baffles. Then he got off only what he could with a broom.

Some engineers claim that soot is always present and forming while a boiler is in operation and that only a certain amount will stay on the tubes, any further accumulation dropping off as it forms, or be carried away by the draft. They claim that, to keep tubes free of soot, a blower must be run all the time, which would be, of course, out of reason.

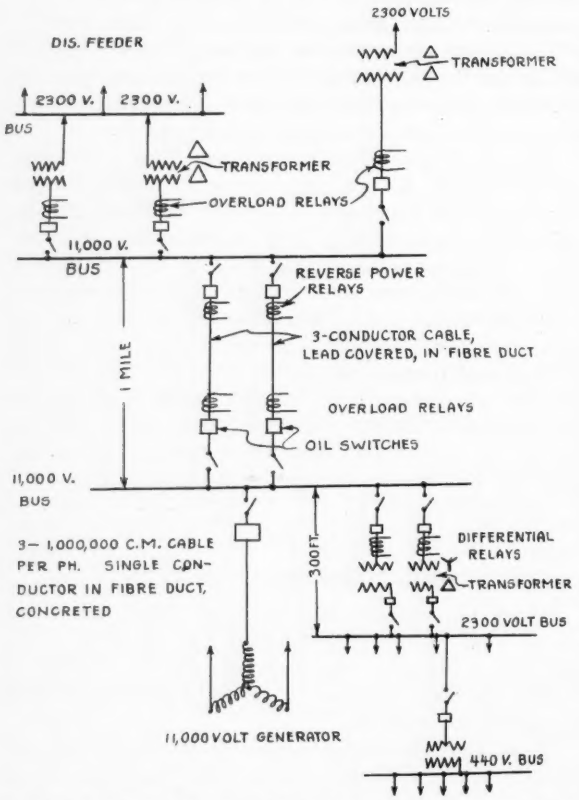
Soot is known by tests to be an effective heat insulator and the less on the tubes the better. It is generally deposited in greater quantities when the boiler is first started and while coming up to pressure on account of contact of the gases with the relatively cold tube surfaces. It would seem that, after the boiler is up to operating pressure and delivering steam would be the logical time to operate the soot blower so as to have clean heating surfaces to start the run. It is difficult to tell, without actual test, just how long to run before another blowing is needed but when temperature of the flue gases rises from 60 to 75 deg. it is reasonable to assume that the cost of steam used in removing the soot will be justified by the savings in coal and labor.

New Bedford, Mass. R. G. Spooner.



Grounding Neutral of One Generator

IN OUR SYSTEM, connections are as shown, the provision of reverse-power and overload relays being such as to insure adequate protection. We have the one generator at 11,000 v. with about a mile transmission to the



IS THERE NEED OF OR ADVANTAGE IN GROUNDING THE NEUTRAL IN THIS SYSTEM? . .

point of distribution over two 3-conductor, lead-covered cables laid in fibre conduit in concrete. One conductor is used per phase from generator to bus. What is the advantage or necessity in such a system of grounding the neutral? Advantages in the case of large public service systems are familiar but do they apply here? I would like the opinion and experience of readers of Power Plant Engineering. D. D. H.

Defrosting Refrigerating Coils

PLEASE TELL me how best to get rid of an accumulation of frost on the box coils in our cold-storage rooms. Brine circulation is employed. We have a good supply of hot water. Could this be used? T. H. D.

A. Warm water may be used, but care should be taken first to pump out all of the cold brine and then see that the defrosting water is warm rather than hot, so that the change in temperature is not made too suddenly, as otherwise an opening of joints may result.

Another method of defrosting which does not result in loss of heat and which has the further advantage of time saving, is to place a flat, slightly perforated pan, filled with calcium chloride brine, above the refrigerating coil, so that the slowly dripping brine will keep the pipes moist. After passing over the pipes the brine should be collected at the bottom and carried off or reused. In this latter method there is an expense due to loss of brine, but its other advantages compensate for this cost.

Brine Circulating Pump

A COLD-STORAGE plant requires the circulation of 500 gal. of brine per min. against a head pressure of 15 lb. per sq. in. If the piston speed is 50 ft. a min., the ratio of piston diameter to stroke is 1⅓ to 1, and an allowance of 15 per cent is made for slip, what must be the dimensions of the pump cylinders of a duplex brine pump for plant?

2. With steam at a pressure of 80 lb. gage, following full stroke, and an allowance of 10 per cent for frictional resistance, what must be the diameter of the steam cylinders for the pump? R. C. S.

A. To get the work done on the brine we should have to multiply the weight of brine by the head against which it is pumped. To get the weight of brine pumped we must multiply the number of gallons, 500, by the cubic inches per gallon, 231, and divide by 1728 to reduce to cubic feet; this divided by the weight per cubic foot of the brine will give the total weight handled. To get the head we multiply the 15 lb. per sq. in. by 144 to reduce it to pounds per square foot and by the weight per cubic foot of the brine. To get the work which must be done by the pump, we have to multiply this work done on the brine by 1.1 because of the 10 per cent friction and by 1.15 to allow for the slip.

Work done by the pump will be the steam pressure 80, times the area of the steam pistons times the piston travel in feet per minute which, for the two pistons, will be 100 ft. Area of the steam pistons will be 3.1416 times the diameter of the pistons squared and divided by 4. If we equate the work done on the brine plus allowance for friction and slip to the work done on the pistons and solve out for the diameter of the pistons we get the following equation:

$$d = \sqrt{\frac{500 \times 231 \times 15 \times 1.1 \times 1.15 \times 4}{12 \times 80 \times 3.1416 \times 100}} = 5.5 \text{ in.}$$

This gives us the diameter of the steam pistons as 5.5 in.

For the dimensions of the brine cylinder, the piston

displacement for the brine pistons will be 500 times 231 times 1.15, allowing for slip, and this must be equal to area of the pistons times piston speed in inches per minute which will be 3.1416 times diameter squared divided by 4 and multiplied by, 100 times 12, which will be the piston speed per minute of both pistons. Equating these values and solving for D we get:

$$D = \sqrt{\frac{500 \times 231 \times 1.15 \times 4}{3.1416 \times 100 \times 12}} = 11.85 \text{ in.}$$

This works out that the diameter of the brine piston will be 11.85 in. and, since the stroke is three-quarters that, it will be 8.88 in.

Air Pressure vs. Duplex Pump for Moving Oil

In our plant, oil is used for process work and is stored in two tanks, 34 and 27 ft. high, with storage capacity of 257,000 gal. Unloading tracks and tanks are some 200 ft. from the power house, the oil coming in 8000-gal. cars. Consumption averages 15,600 gal. in 24 hr.

Oil is transferred from cars to tanks by compressed air, using 21 lb. pressure from a single stage compressor which has a steam rate of 35 lb. a horsepower-hour. A 1-in. air line runs to the top of the car and a 1-in. steam line passes through the 2½-in. pipe leading from car to main discharge line. Steam is at 120 lb. pressure at the tank and flows through an opened ⅜-in. valve, the end of the line being open and steam blowing against the fittings on the car through the equivalent of a ¼-in. opening.

To hasten flow of oil up the vertical pipes, which discharge into the tops of the tanks so as to stir up the oil in them as little as possible, air at 70 lb. is used on the booster ejector principle, this air coming through a ¾-in. line from a 2-stage compressor whose steam rate is 40 lb. per horsepower-hour.

Three cars are spotted at a time which takes 4 men 10 min. each car at 45c an hour to let an empty car down the track and place a loaded one. The cars must be unloaded as quickly as possible as tracks are also used for sand cars which cannot be delayed. To tap, make connection to oil discharge and to replace valve on empty car requires two men ½ hr. for each car at 45c an hour.

According to a test, our boiler evaporation is 6.88 lb. of water per lb. of coal, from and at 212 deg., coal costing $3.55 a ton in the bunkers.

What is the approximate cost of unloading an 8000-gal. car which requires 2.5 hr. on the average to empty?

Also what boiler horsepower will be required? And what steam would be used, if a pump with 9-in. steam, 5¼-in. oil cylinder and 10-in. stroke, with allowance for slippage and friction, pumped the oil against 32 ft. head with 4 ft. head on the suction end? G. M.

A. For air used in the top of the tank, the amount will be that needed to displace the oil. For 8000 gal. at 231 cu. in. per gal., this will be 10,700 cu. ft. at 20 lb., or 27,600 cu. ft. of free air.

$$(10{,}700 \times 34.7 \div 14.7 = 27{,}600)$$

For the booster air at 70 lb., the head pressure of oil at 16 deg. Beaume, 59.8 lb. per cu. ft. and 32 ft. average head, will be $59.8 \times 32 \div 144 = 7.1$ lb. per sq. in. Friction head is only a guess but to be safe, allow a total head of 20 lb. The air will then flow under a free pressure of $70 - 20 = 50$ lb. per sq. in. and tables of the Compressed Air Society (see Power Plant Engineering, Dec. 1, 1925, p. 1220) give the flow through a ¾-in. orifice at 50 lb. pressure as 522 cu. ft. min. or for 2.5 hr., 78,500 cu. ft. of free air.

Tables of this society also show that, for a single-stage compressor at 20 lb. pressure and water rate 35 lb., 4 lb. steam will be used for 100 cu. ft. of free air, or for 27,600 cu. ft., $276 \times 4 = 1104$ lb. For a 2-stage compressor at 70 lb. pressure and water rate of 40 lb., 9.4 lb. steam per 100 cu. ft. air will be needed, or for 78,500 cu. ft., $785 \times 9.4 = 7360$ lb. The total is 8464 lb. steam for 2.5 hr. or 3380 lb. an hour.

For heating, the flow may be found from Napier's rule: Pounds per second = absolute steam pressure × area of opening in square inches ÷ 70. For 120 lb. gage and ¼-in. opening, area 0.05 sq. in., this becomes: wt. $= 135 \times 0.05 \div 70 = 0.0964$ lb. per sec. For an hour this is 346.8 lb.

Total steam per hr. is, then, $3380 + 347 = 3727$ lb., which, at 30 lb. an hr. for a boiler horsepower, calls for 124 hp. This is based on assumptions and may be inaccurate by 10 per cent.

So far as the pump is concerned, a 9 by 5¼ by 10-in. duplex at 27 r.p.m. would pump 3.6 gal. a revolution or 5840 gal. an hour. It would, then, require $8000 \div 5840 = 1.37$ hr. to empty one car.

If the friction and velocity head is assumed as 22 ft., the total head will be $32 - 4 + 22 = 50$ ft. With oil at 8 lb. per gal., the weight will be $8000 \times 8 = 64{,}000$ lb. and work done $64{,}000 \times 50 = 3{,}200{,}000$ ft. lb. This will be done in 1.37 hr. or 82.2 min. so that the horsepower will be $3{,}200{,}000 \div (82.2 \times 33{,}000) = 1.177$ hp. net, or at 58 per cent efficiency, $1.177 \div 0.58 = 2.03$ indicated horsepower. Allowing 120 lb. of steam per horsepower-hour, would give $2.03 \times 120 = 240$ lb. an hr. as against 3380 lb. an hr. for the compressed air method. Boiler horsepower for the pump and heating would be $(240 + 347) \div 30 = 19.5$ b.hp. as against 124 b.hp. for compressed air and heating. A further saving could be made by using exhaust steam from the pump for heating the oil.

Air-Compressor Rotation

Should an air compressor run "under" or "over"? A. M. C.

A. This has been a point of discussion as to engines and compressors ever since we can remember. In most cases it doesn't matter, so far as the machine itself is concerned.

Stationary engines usually run over, so as to bring thrust on the lower guide, since it is somewhat easier to take up wear from the bottom. Also, if belt drive is used, this brings the tight side on the bottom and gives better wrap on the pulleys.

One of the engineers of the Sullivan Machinery Co. states that it makes no difference whether their compressors run over or under, since both top and bottom guides are adjustable. The horizontal compressors run over because that makes their splash system of lubrication work properly.

EDITORIAL COMMENT

Smoke Prevention in the Early Fall

Just why smoke prevention, a subject of such importance to the public welfare, should be so intimately connected with politics is perhaps a debatable question. The fact remains, however, that in spite of reasonably effective enforcement in a few cities the majority continue to exist under the semi-darkness of a smoke pall during the winter months.

Poor furnace design, often the work of architects not properly qualified in this branch of engineering, is partly to blame, although owners by hiring cheap help and trying to burn cheap coal must bear the major part of the charge. Fortunately, most cities have ordinances which, if properly interpreted and enforced, would remedy the situation but politically controlled, there is little chance for fair and impartial consideration of a subject requiring expert and practical combustion knowledge.

If enforcement is to be attempted, obviously the proper time to start is in the early fall when heating plants coming into service gradually can be kept track of. A few well directed and well advertised examples of the early offenders will cause others to take active means to escape a similar fate.

Recently one of Chicago's prominent bank buildings celebrated the first cold day by a dense smoke screen from its boiler room. After repeated warnings the health commissioner's men took charge, pulled the fires and, to complete the action, turned the fire hose in on the coals. Rather hard on the furnace perhaps but effective. Before the morning was over the plant was operating again, this time with a haze which, although it might have occasioned some concern to a Diesel operator, looked pretty good for a heating plant just getting into action. A few examples, be they political or otherwise, cannot help having beneficial results.

Fresh Air, Please

As winter approaches, windows are closed more of the time and occupants of buildings feel the depressing effect of air which is not 100 per cent pure. In cities especially, this condition is noticeable because of the smoke from many chimneys that have not learned the art of smokeless combustion. As a result, colds, pneumonia, bronchitis and other pulmonary diseases become prevalent and are likely to continue so throughout the winter.

To put outside winter air into proper condition for breathing requires more than merely bringing its temperature up to a comfortable degree. Proper humidity is extremely important and dust-laden air is the cause of much sickness. Being a mechanical problem, the process of air conditioning in buildings is placed under the care of the engineer. Heating and ventilating buildings are no longer new problems but in recent years the demand for clean, humidified air and, in the summer time, air that has been cooled, has placed upon the engineer additional duties which are not generally understood.

Fortunately the equipment developed for air conditioning can be provided with automatic control devices that maintain given air temperature and humidity; nevertheless, the engineer must understand the problems and keep his machinery in good condition. Air that contains too much moisture is just as disagreeable and harmful as air that is too dry. More colds are caused by overheating buildings than by underheating them. Temperature, also humidity, should be governed to suit the activities of the occupants of the rooms and investigations have shown that a variation of but a few degrees will have a marked effect upon the work accomplished by the occupants.

Just how air is conditioned in a department store is told on other pages of this issue and it would seem that the services of the engineer are again called for when the gasping occupants of buildings demand fresh air.

Chimney Design

Much has been written concerning the design of chimneys from the purely engineering standpoint; that is, as devices for producing a certain desired draft in furnaces. But modern developments in the design of furnaces and in the use of forced and induced draft fans for producing proper furnace conditions bid fair to bring about changes in chimneys that will greatly improve them from the strictly architectural or artistic viewpoint, which, as we have pointed out previously, ought not to be neglected. We have often wondered, for example, why it is that many plants using both forced and induced draft fans are equipped with chimneys which tower into the air for 150 ft. or more and give a decidedly top-heavy appearance to the power plants they serve.

Let us add here that we recognize the fact that, in many cases, city ordinances specify minimum heights for chimneys. In addition, there may be cases in which it is imperative that flue gas from boilers be discharged well above the roofs of surrounding buildings, as in the case of hospitals or hotels. There still remain, however, many cases in which such provisions are unnecessary.

Recently, we have seen several interesting illustrations of the way in which chimneys in office and mercantile buildings can be concealed in towers or constructed of the same materials as the building, such as brick or concrete, and made a part of the architectural design. Several power and heating plants have recently been designed in which considerable attention has been paid

to the design and appearance of the chimneys. In one or two cases they do not appear above the roof line at all.

There is no reason for changing power plants into Greek temples or climbing piles of Gothic masonry, but we feel that more attention can be given to chimney design from the strictly aesthetic viewpoint than has been given in the past, especially when the chimney in question is not designed for natural draft.

Responsible Leadership

Every engineer of a power plant is an executive of his company. He must plan the operation of the plant to get best results or he is not meeting the responsibility which is his.

In the plant having a considerable force of employes, he has an even greater task for he is the leader of the organization. He is responsible for results but must achieve them largely through the work and interest of others. He must gain their confidence and their loyalty to himself and his company.

Playing the square deal to everybody,—company and men—an open mind to receive and adopt suggestions from above or below, dependability in routine operation or in emergencies are the foundation on which he must build to secure the confidence of the company and the men. To the men, he represents the company. To the company officials he represents his plant organization. Both ways he is in a position of leadership with great influence if he accepts and proves his ability to meet his responsibilities.

Such leadership is not attained, except in rare instances, by natural aptitude alone. The capacity must be there but the ability must be developed by careful study of men and problems and by taking thought as to the best ways to handle both. Proper equipment properly operated by a well trained personnel will get results of which the power plant engineer may well be proud and will prove that he is a responsible leader, who appreciates the worth-whileness of his task.

Off Duty

Between the epoch making discoveries of newspaper reporters and the unique, at times bizarre, scientific contributions of our members of Congress, the scientific world has a difficult time keeping abreast of developments. True, in our great scientific laboratories a certain amount of mediocre research is conducted by our scientists and occasionally they seem to hit upon something as, for instance, the discovery of the electron, the gas filled lamp, Insulin, the x-ray, atomic hydrogen and other such commonplace items, but nothing of a really startling nature.

For the startling discoveries—those that electrify and that hold us spellbound, we must turn to the newspapers. Take for instance the astonishing announcement in a recent issue of the world's greatest newspaper, "Vienna Savant Finds Way to Split Electron." That, to our way of thinking, is something to shout about.

Amazing as this headline is, it gives no intimation of the side splitting fable that follows. Ever since we first read it we have been sitting around in open-mouth bewilderment. To rewrite it would be criminal, so we reproduce it here, verbatim.

"Ever since the American scientist, Rutherford, succeeded in splitting the atom, scientists have been hoping to produce light, heat and energy by breaking down the electron, which, until now, has been the smallest unit of electricity. Prof. Ehrenhaft (the Vienna savant) says he is able to discern the component parts of the electron, namely, platinum, gold, silver, nickel and selenium.

' He used in his experiments a magnet with poles two millimetres apart. The electron under a powerful microscope, appeared to have component parts of a diameter of one hundred thousandth of a centimetre each. These were ball shaped. When electrified they possessed only half the amount of electricity of an electron."

Shades of Dr. Abrams! What next? Where will these newspaper fellows stop? Since the Akound of Swat passed to his eternal reward, we have heard nothing as good. Splitting the electron! Poor Dr. Millikan, what a blow it must be to him.

But, as usual with press reports, the account is woefully incomplete. The learned gentleman who placed this startling news on the wire says that the components of the electron were ball shaped. Fine, but what else? What about their color or appearance otherwise? Were they pink, green or mauve; were they wrinkled or smooth; did they have scales like a fish or fur like a bunny; were they a wild lot or did they possess the markings of respectability; were they blondes or brunettes (gentlemen, you know, prefer the former type); and what was inside of them? These and a thousand other questions beseige our minds, but must remain unanswered. Pure carelessness, nothing else.

Another thing, our scientific scribe refers to the *American* scientist, Rutherford. Sir Ernest, should he read the article, will no doubt feel highly complimented, but as ardent boosters in the great cause of truth, we do not think it quite fair. America has enough to be proud of with such institutions as the Atlantic City Beauty Contest, Dr. Frank Crane and Father's Day without spiriting Sir Ernest Rutherford away from Jolly England. Little things like that often start big wars.

There is another serious angle to the situation. Think of the shock with which the news of the discovery must have hit the ball bearing people. Being ball shaped, these electrons will naturally find a ready market for use as ball bearings in wrist watches, egg beaters and salad forks. True, they are still somewhat small but it has been proved that they can be made larger. In our time the electron was much smaller, in fact, for some years it has been known that there are as many electrons in a single drop of water as there are drops of water in the Atlantic Ocean. But they are growing babies. Already they are a hundred thousandth of a centimeter across and our savant can see them with his microscope. Some microscope! Without doubt, they will continue to grow and before long we will see a full size picture of a dissociated adult electron weeping for its mate on the front page of one of the tabloids.

MORE THAN 23,000 persons lost their lives in industrial accidents during the past year, regrets the National Safety Council.

Electric Flow Meter Has Interesting Features

By Thomas R. Harrison*

BECAUSE OF the great advancement in engineering practice, need for systematic and accurate measurements of conditions and quantities involved has grown rapidly, and desirability of locating meters at points most convenient to users is keenly appreciated.

Flow meters of the electrically operated type are found especially adaptable, as the indicator may be so located as to be clearly seen as a guide to firing, while the recorder and integrator may be grouped with other recording instruments. Also indication and record of conditions inside a high-pressure steam or water pipe may be had without transmission of mechanical motion. Suitable means of securing reliable indication and record must, however, be used.

Principle of Operation

In the new electrically operated flow meter made by the Brown Instrument Co., the manometer, A, Fig. 1, operates in response to differential pressure caused by flow of the liquid through an orifice B. When the rate of flow increases, mercury is depressed in chamber A_1 and rises in chamber A_2, the difference in mercury level in the two chambers being a measure of the rate of fluid flow through the orifice. When the flow increases from zero to a maximum value, a float which rides on the mercury surface in chamber A_1 is lowered from the position indicated by dotted lines to a lower position as indicated by the solid lines. The float is made of non-corrosive metal and chamber A_1 has a moulded bakelite lining, ribbed on the inside, insuring freedom of action at all times. An armature C of transformer iron is supported by the float on a non-magnetic rod D and the armature is raised and lowered in accordance with the motion of the float.

This armature travels inside of a rust-proof, non-magnetic tube which has high electrical resistance and great mechanical strength. The pressure of the fluid being metered is confined within this tube and the electrical inductive winding EE_1 which is slipped over the outside of the tube has excellent magnetic linkage with the armature which moves inside. At the same time, the coil is under atmospheric conditions only and is protected by a cover F.

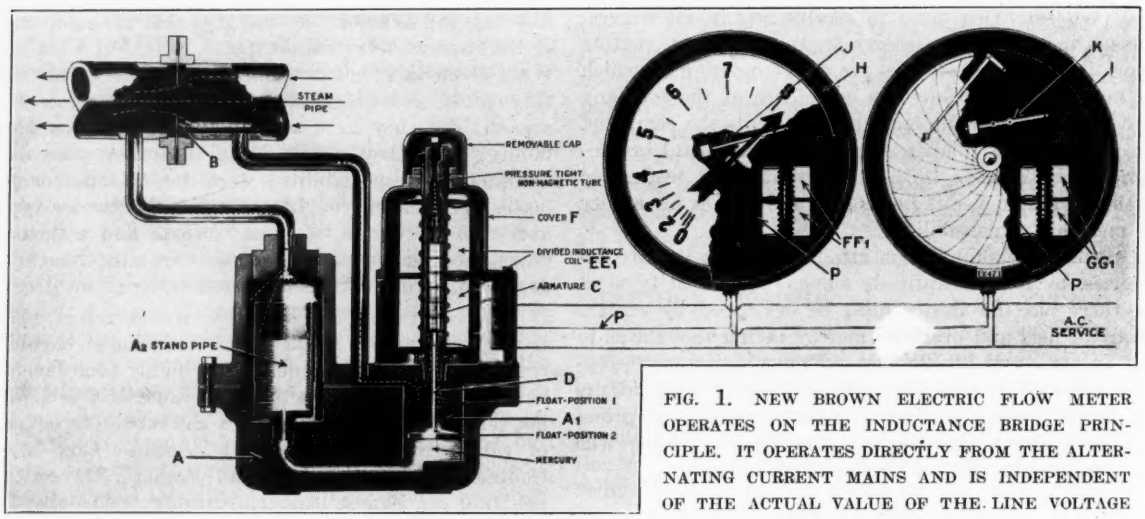


FIG. 1. NEW BROWN ELECTRIC FLOW METER OPERATES ON THE INDUCTANCE BRIDGE PRINCIPLE. IT OPERATES DIRECTLY FROM THE ALTERNATING CURRENT MAINS AND IS INDEPENDENT OF THE ACTUAL VALUE OF THE LINE VOLTAGE

Outer ends of the divided winding EE_1 are connected directly across the service mains of an alternating-current supply line with connections running from these ends directly to the outer ends of similarly divided inductance coils FF_1, which operate an indicator H, and GG_1 operating a recording instrument I. Armatures are hung on counterbalanced arms J and K in the two instruments. The junction points between the two parts of divided coils EE_1, FF_1 and GG_1 are all connected together by a neutral wire P and, when thus connected, the coils form the self adjusting inductance bridge which is the outstanding basic feature of this flow meter.

When the armature C in the manometer is raised or

*Research engineer, The Brown Instrument Co., Philadelphia, Pa.

lowered by a change in fluid flow, the relation between the voltages across the two parts E and E_1 of the winding will be changed. This causes the currents in the two parts FF_1 of the indicator coil and also in the two parts GG_1 of the recorder coil, to become unequal, hence, the armatures of the indicator and recorder move to new positions corresponding to the position of the armature C and the meter readings are adjusted accordingly by means of the gearing or linkage shown.

More briefly, the operation of the inductance bridge may be summarized by saying that the armatures of the instruments move in accordance with the motion of the manometer armature as the latter is moved up and down by the mercury float. Since the positions assumed are such that the relative voltages across the two parts of each coil are the same, the operation of the instrument is independent of the actual value of the line voltage. No continuing current flows in the neutral wire and the currents in the two halves of each divided coil are equal except where the armatures are being moved.

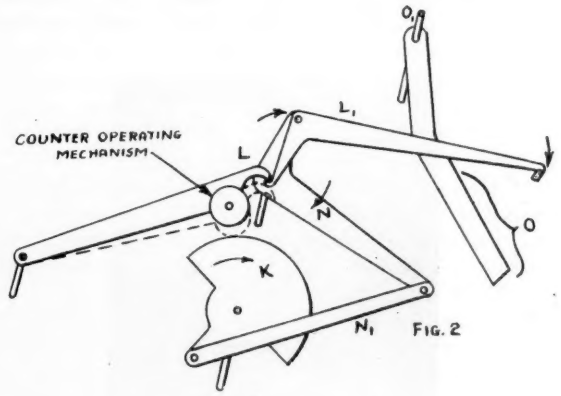


FIG. 2

FIG. 2. THIS INTEGRATING MECHANISM REPRODUCES THE SQUARE ROOT LAW

FIG. 3. CAM ACTION OPERATES THE COUNTER AND THE TIME RECORDING PEN

Integrator and Recorder Are Combined

In order to make use of the simple inductance bridge method of operation, a special type of integrator was developed which increases the counter readings in proportion to the square root of the angular deflection of the recorder pen arm, this being the relation of the flow to the pressure difference across the orifice. Attached to the gear train which drives the recorder chart is a sector of a disc K, Fig. 2, which rotates at a constant rate. A roller L is normally held up by latch L_1, out of contact with the sector. Position of the sector when the latch is tripped depends upon the rate of flow and thus, before the sector passes out of contact with it, the roller is rotated through an angle proportional to the rate of flow. After the sector passes beyond the roller, the latter is again latched up by L_1 and the process is repeated at regular intervals.

This square root relation existing between rate of flow and pressure difference (the latter being translated into recorder pen travel) is reproduced in the relation between angular travel of disc L and pen deflection by means of the oscillating latch carrier N, driven by the rotating sector K, through a link N_1.

Tripping blade O, which is attached to the recording pen shaft O_1, releases the latch at the proper point, according to the reading of the instrument, the motion of the pen never being restricted by the tripping operation.

Angular relation between the uniform rotation of sector K and the rocking motion of arm N is almost exactly a reproduction of the square root law through a large portion of the downward motion of arm N, the slight departure from the exact relation desired being taken care of by the shape of tripping blade O, which is very thin, and holds O fast against a plate while latch L_1 is being tripped.

Parts are simple and can be made accurately under practical manufacturing conditions so that the square root relation is always reproduced correctly by the mechanism and the simple integrating mechanism permits the employment of the inductance bridge method of transmitting the meter readings.

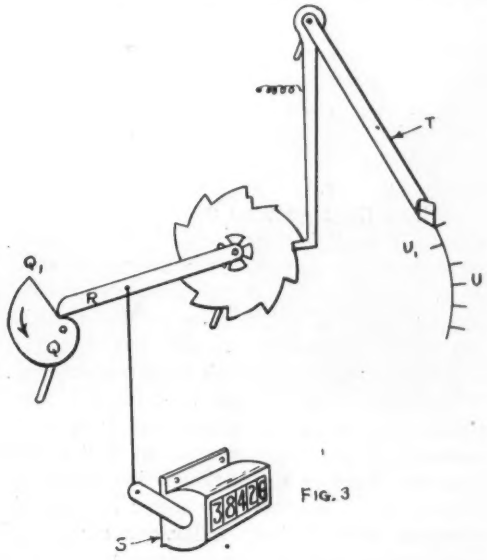


FIG. 3

When roller L has turned through a definite number of revolutions, a pawl is released which engages with a toothed pinion of the chart-driving gear train. This causes cam Q, Fig. 3, to make one complete revolution after the pawl is released; then the cam remains at rest until the roller again completes the proper number of revolutions.

As the cam Q advances, an arm R is gradually raised, lifting the arm of ratchet counter S until the high point Q_1 of the cam passes, then the cam arm falls quickly and advances the reading of the counter by one full unit, no half-way position being possible.

Each time the cam arm falls, the time recording pen T makes a jog U in its record line, every tenth jog, U_1, being in the opposite direction, to facilitate counting when desired. The five-figure integrator dial S can be read at any given hour or hours of the day and records made on a chart or elsewhere if desired; but the record of the recording planimeter can take the place of these counter readings and affords the added advantage of making a record from which the total flow can be read off for any desired fraction of a day, at any subsequent

time which may be convenient, eliminating the necessity of having an observer on hand at the proper hours to note the readings of the counter as they occur.

A series of printed charts is chosen with a fixed ratio between successive ranges. The manometers also are arranged to be adjusted for several appropriate ranges. This simplifies the choice of an orifice plate, the size of which depends chiefly upon the density of the fluid and the pipe size. With such an orifice the apparatus is easily adjusted for successive chart ranges by using a stand-pipe of proper size in the manometer. This is useful where the average load changes from time to time, for then the apparatus can be re-adjusted by changing the manometer stand-pipe, instead of changing the orifice plate, which is much less convenient.

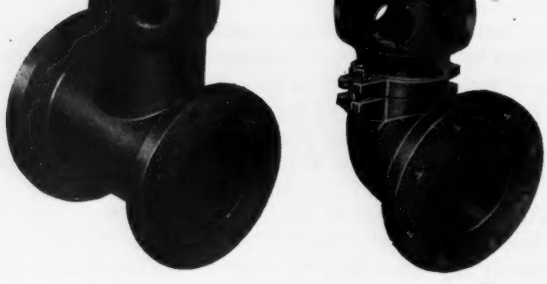
Various manometers for use with steam, operate on successive maximum pressure differentials, increasing by intervals of about 60 per cent, ranging from 1.6 in. to 16 in. of mercury. This series has six ranges, the choice of a suitable manometer depending upon velocities encountered. Any manometer of the series, however, may be converted into the most sensitive one by simply opening a valve. This adapts the meter for use with one of the lower range charts, making it easily convertible for low-load periods, which will be a distinct advantage in many types of service.

Where the apparatus must work on very low pressure differentials, an especially sensitive type of manometer is provided, the most sensitive of which gives full deflection of the meter on a pressure difference of ½ in. of water, although the operating force of the meter mechanisms of this high-sensitivity series is as great as that of the high-range manometers.

Because of the simple inductance bridge principle upon which all of these instruments operate, electrical connections are made permanent and external to the pressure chamber and action is independent of voltage fluctuation. This new flow meter is adapted for measuring the flow of steam, water, gas, air and other fluids.

Spray Pond Fixtures Improved

IN ORDER to simplify the installation of spray ponds, decrease maintenance charges and cut down the pumping head caused by friction, the Yarnall-Waring Co. of Philadelphia has designed some special fittings. The illustration on the right is the new hump tee changed from the original design by the substitution of a spherical for the old cylindrical form distributing head. The new head enables the spray arms to be screwed in easier and gives better support to the arms after they are in place.

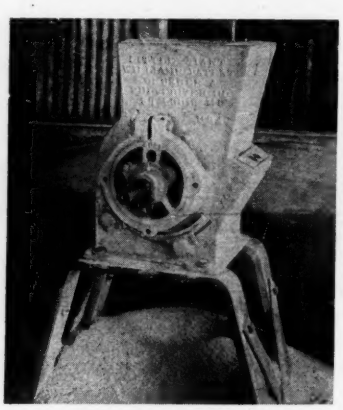


THESE SPRAY POND FIXTURES ARE DESIGNED TO DECREASE OPERATING COSTS OF COOLING PONDS

Special ells are provided for the end of the line to avoid the use of blank flanges, the illustration on the right showing one of these pieces with the distributing head cast separate, to be bolted to the main casting. Special straight or eccentric tees incorporating this feature are also available.

Small Grinder Prepares Old Firebrick for Patches

BURNING old firebrick into lasting furnace walls and patches has been made easy by the Little Giant Grinder manufactured by the Williams Patent Crusher & Pulverizer Co., St. Louis, Mo. Heavy manganese steel hammers rotating at high speeds crush the brick to ¼ in. or smaller against renewable breaker plates. Heavy duty S K F ball bearings in grit proof housing eliminate friction and reduce power consumption to the minimum.



THIS MACHINE OPERATES AT ABOUT 1800 R.P.M. TO GRIND OLD FIREBRICK FOR USE IN MAKING MONOLITHIC FURNACE WALLS

For monolithic linings 75 per cent crushed brick and 25 per cent high temperature cement, worked to the thickness of griddle cake batter, should receive a surface coat of 85 per cent crushed brick, 10 per cent high temperature cement and 5 per cent portland cement. Brick for the first should be crushed ¼ in. or finer and for the finish or surface coat to at least 1/16 in. Sizes can be regulated by moving the breaker plate nearer to or farther away from the revolving hammers.

Four sizes in either belted or direct motor drive are available ranging in capacity from 1000 to 4000 lb. of firebrick an hour. The same grinder can be used for reclaiming and shredding old asbestos by replacing the heavy manganese steel grate with a punched steel plate cage or screen. Measured in pounds per hour the capacity with asbestos is about 50 per cent of the capacity of the same machine when grinding bricks.

Fifth Power Show Promises New and Interesting Features

ARRANGEMENTS are being rapidly perfected for the Fifth National Exposition of Power & Mechanical Engineering to be held at the Grand Central Palace, New York City, from Monday, Dec. 6., through Saturday, Dec. 11, 1926, inclusive. The exposition will open at 12:00 noon each day and will close at 10:30 p. m.

In order to serve as a clearing house of the latest information concerning developments in power and mechanical engineering, a complete representation from important manufacturers in the following lines will be shown: heat and power generating apparatus; hoisting and conveying equipment; power transmission equipment; machine tools; refrigerating machinery; heating and ventilating machinery.

Of additional interest to those attending the exposition will be the annual meeting of the American Society of Mechanical Engineers to be held in the Engineering Societies' Building, 29 West 39th St., from Dec. 6 to 9. In addition, the American Society of Refrigerating Engineers will hold its annual meeting at the Hotel Astor from December 7 to 9.

The exposition will feature a number of educational exhibits, among which will be models of the Flettner rotor ship, diagrams and models showing isometric pipe layout and models of important power plants and power machinery. .

It is expected that the fifth exposition will include exhibits of 500 manufacturers and will occupy four floors of the Grand Central Palace. The exposition held in December of last year was visited by approximately 85,000 engineering and industrial executives. Admission to the exposition is by invitation.

New York Approves St. Lawrence Power Lease

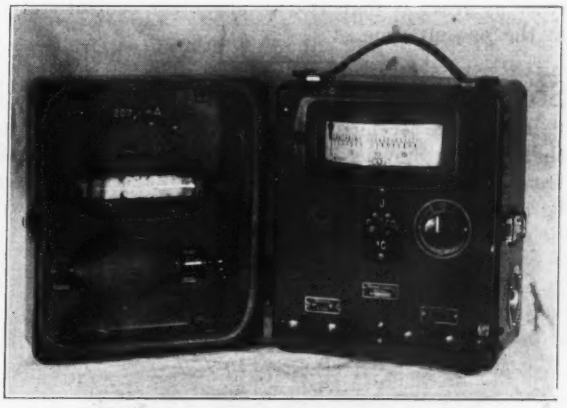
ANNOUNCEMENT HAS JUST been made that the New York State Water Power Commission has adopted the terms of a lease which it expects to grant after a hearing on October 15 for the development of at least 1,000,000 hp. on the St. Lawrence River by private capital. The form provides for a 50-year license, at the end of which time the entire power plant shall revert to the state of New York.

Three years are allowed for preliminaries, at the end of which period work must be started and must be completed five years after that. The state treasury will receive approximately $250,000 a year for the use of the power site when it is first operated and this is to be increased to a minimum of $1,000,000 after the first ten years of operation. The terms of the lease provide that existing St. Lawrence canal navigation and proposed St. Lawrence ship canal construction be safeguarded and that the power company must build the necessary locks to permit navigation to make its way past the power dam.

The license provides that a single dam is to be constructed, the site named being near Barnhart Island, about 40 miles from Ogdensburg. The complete cost of the project will be about $250,000,000. Provision is also made that the dam and power houses shall be built so that at least one-half of the power developed shall be on the New York state side, even if this requires relocation of the Canadian boundary line.

Portable Electric CO_2 Instrument Put on Market

TO MEET demands for a quick, accurate, portable CO_2 meter, the Bacharach Industrial Instrucent Co. has developed a new 14½-lb. electric instrument operating on the same principle as their permanently installed meter. Gas examples are drawn through a small calcium chloride and cotton filter by means of a hand aspirator which folds conveniently in the cover of the case when not in use. Operating current is furnished by three standard dry cells and the readings are indicated on a precision indicator arranged in the top of the case. No liquids, or expert operators, are necessary.



NEW PORTABLE ELECTRIC CO_2 METER

The CO_2 is indicated instantly saving much time over the use of an Orsat while if desired continuous indications can be taken over periods of time up to three hours.

Zero adjustment is provided by means of a variable resistor which cuts resistance in or out of the ammeter circuit as desired. Temperature measurements can be taken on the same instrument by connecting any standard thermocouple to the proper binding posts and determining the temperature from the millivolt scale reading and a calibration curve of the thermocouple.

A. S. M. E. Elects Charles M. Schwab President

AT THE ANNUAL ELECTION of officers of The American Society of Mechanical Engineers, Charles M. Schwab was elected president of the Society for the coming year. Mr. Schwab will formally assume his new office at the annual meeting of the Society in New York early in December, succeeding William L. Abbott of Chicago.

Other new officers announced by the tellers at this time are: vice-presidents, Charles L. Newcomb, Everett O. Eastwood and Edwards R. Fish, three new members of Council, Col. Paul Doty, Ralph E. Flanders, and Conrad N. Lauer. Erik Oberg, editor of Machinery, has been re-elected treasurer of the Society.

Boston to Install 63,000-Kw. Single Cylinder Turbine

AT THE EDGAR station of the Edison Electric Illuminating Co., of Boston, there is to be installed a single cylinder, single-flow, steam turbine, rated at 63,000 kw. or 84,000 hp. This machine, which will be manufactured by the General Electric Co., will operate at 350 lb. steam pressure, 725 deg. F., with exhaust pressure at one inch absolute. It will drive a 60,000-kw. main generator and a 3000-kw. auxiliary service generator. Normal generator voltage is to be 14,000 v., 60 cycles.

Equipment now in service in the Edgar station includes two 32,000-kw. turbine generators and a 3000-kw. unit. The 3000-kw. turbine, which operates at a pressure of 1200 lb. steam pressure, is unique in that it is the first to operate at such high pressure—about three times as great as the average pressure in use today and twice as great as that used in any other central station at the present time.

Stevens Hotel to Be Opened Next March

FROM THE accompanying illustration it would appear that the new Stevens Hotel, which is located on the lake front in Chicago, is nearly completed. It will, however, be about the 1st of March, 1927, before the hotel will

be put into service. At present the machinery foundations are in, two boilers are in the course of erection and two pumps are installed. Few pieces of the air conditioning system are installed but it is expected that the power plant equipment will be ready for service at the time the hotel is opened to guests.

The structure has 25 stories above and four below the sidewalk level and contains 3000 guest rooms all provided with an abundance of daylight through the provision of five open courts. The cubical contents of the building is 20,000,000 cu. ft. and the area covered is 80,000 sq. ft. .Every modern mechanical and electrical convenience known in hotel service will be provided. Seven water-tube boilers will be installed, electric generating capacity of 3100 kw. will be provided, a refrigerating plant of 500 t. capacity is planned and in the heating system will have a total of 130,000 sq. ft. of radiation.

Death of Charles R. Huntley

CHARLES RUSSELL HUNTLEY, president of the Buffalo General Electric Co., died at his home in Lancaster, N. Y., on September 17. He was 72 yr. old.

For many years Mr. Huntley had been a leader in the industrial life of western New York. He was born in 1853 at West Winfield, N. Y., and educated in the schools of that city and of Utica. After being employed by the Remington Arms Company for three years, he went to the American Transfer Company in 1877 and, after several exciting years in the oil fields, went to Buffalo to enter the electrical business. His first employment here was as general manager of the Brush Electric Light Company. When this concern merged with the Buffalo General Electric Company in 1892, he became first vice president and general manager, being elected president in 1896. He was also an officer in other public utility companies and a director of several banks. He also served as president of the National Electric Light Association.

News Notes

AT THE GREENBRIER, White Sulphur Springs, W. Va., the American Institute of Steel Construction, Inc., New York, will hold its fourth annual convention from October 26 to October 30, next. An interesting program of technical papers by prominent men of the steel industry will be interspersed with entertainment features.

AT ITHACA, N. Y., on November 11 and 12, the Administrative Board of the American Engineering Council will meet to receive reports from various committees which have been active during the summer. Among the topics to be discussed are safety and production, registration of engineers, government reorganization, and jurisdictional strikes in the building industry. Dean Dexter S. Kimball of Cornell University, President of the Council, will preside.

E. L. FISHER has recently been elected vice-president and general manager of the Illinois Power & Light Co., Chicago, Ill., succeeding W. A. Baehr. Dwight Holmes has been elected secretary to succeed Scott Brown; and P. L. Smith has been chosen as treasurer to succeed P. C. Dings.

A. W. CUDDEBACK, president of the American Water Works Association and vice-president of the Passaic Water Co., Passaic, N. J., has become connected with the Federal Water Service Corporation as vice-president in charge of operations, with headquarters at New York.

LINK-BELT CO., Chicago, Ill., has just opened a branch office in Utica, N. Y., at 107 Foster Bldg., 131 Genessee St., in charge of F. P. Hermann, Jr.

CARL G. SCHLUEDERBERG has been appointed general manager of the George Cutter Co., South Bend, Ind., according to announcement made by F. A. Merrick, vice president and general manager of the Westinghouse Electric and Manufacturing Co. The George Cutter Co. is a subsidiary of the Westinghouse Electric Co. in which street, industrial and commercial lighting equipment and storage battery chargers are manufactured.

E. G. RALSTON has become chief mechanical engineer for the Indianapolis Light & Heat Co., Indianapolis, Ind., to succeed Thomas N. Wynne, resigned. Mr.

Ralston will act as head both of the mechanical and electrical engineering departments until further notice. He has been connected with the company in various capacities since 1913.

THE PHILADELPHIA ELECTRIC CO., Philadelphia, Pa., has recently completed the installation at its Schuylkill station of the largest self-cooled single-phase transformers constructed up to the present time. The units are arranged in two banks, with total rated capacity of 120,000 kv.a. They were constructed by the General Electric Co., and were shipped to their destination assembled in their permanent tanks, immersed in dry oil, thus eliminating the usual drying process. The new transformer installation controls a tie line between the Schuykill and Chester stations of the company.

T. A. RADY, Detroit, Mich., combustion engineer, has been appointed chief smoke inspector for the city.

AMERICAN BROWN BOVERI ELECTRIC CORP., New York, has been awarded a contract by the board of public utilities, Jamestown, N. Y., for a new 6000-kw. turbo-generator unit for the Municipal Electric Plant at Jamestown.

WALTER C. MARMON, heretofore president of the Indianapolis Light & Heat Co., Indianapolis, Ind., has been elected chairman of the board of directors. Norman A. Perry, previously secretary of the company, has been elected president to succeed Mr. Marmon.

THE LAKE SHORE POWER CO., Toledo, Ohio, operating the Toledo & Indiana Interurban Co., Toledo & Indiana Transportation Co., and other power and traction utilities has been acquired by Henry L. Doherty & Co., New York.

THE OTTER-TAIL POWER CO., Fergus Falls, Minn., has work nearing completion on a new power plant at Washburn, N. D. The plant will burn lignite fuel and is located close to deposits of lignite. The site fronts on the north bank of the Missouri River from which cooling water will be secured.

THE MISSISSIPPI CENTRAL POWER CO. has been chartered under the laws of Maryland with a capital of 1,000,000 shares of stock without par value assessed by the state for taxation at $100,000,000. It is understood that the company will construct new power plants and transmission lines as well as ice and refrigeration plants.

THE EASTERN SHORE GAS & ELECTRIC CO., Maryland, is planning a new central station capable of serving the entire Delaware-Maryland-Virginia Peninsula for many years. The board of directors has approved expenditures of over $2,000,000 for this work and it is stated that new construction will begin within the next few months.

THE OSTER MFG. CO., Cleveland, Ohio, has recently brought out an improved Saunders type pipe cutter designed to convert a costly hand job into an economical power operation. Designed primarily to meet the demand for a strong sturdy tool that will track readily when turned by a mechanical drive, such as the Oster power driven pipe threader, the new cutter is also applicable to hand use. Special reinforcement where the greatest strain occurs is provided so that cutting-off speed can be increased. The new cutter is made in two sizes, one of which serves for pipe ⅛ to 1 in. and the other for ½ to 2-in. pipe.

THE PUBLIC SERVICE CORPORATION, Newark, N. J., operating the Public Service Electric & Gas Corporation, is now conducting five cadet courses, including a five-year course in all branches of public utility service, and three-year courses in the electric operating, gas operating, railway operating and commercial departments. The courses were started about 20 yr. ago, and have produced many graduates now the heads of various departments of the organization. Selections are made annually for the courses from a group of prominent eastern colleges, taking seniors to the number of about 50, who are interested in this branch of work and whose college records indicate satisfactory preliminary development. The majority of the cadets are graduates from such universities as Princeton, Yale, Harvard, Lehigh, Brown, Lafayette, Rutgers, Cornell, Pennsylvania, Dartmouth, Stevens and the Massachusetts Institute of Technology.

THE ALABAMA POWER CO., Birmingham, Ala., has completed the installation of the first unit of its hydro-electric plant known as the Martin Dam Power Station on the Tallapoosa River, Alabama. The first generating unit has a capacity of 45,000 hp., and will be supplemented by three other similar units to give a total capacity of 180,000 hp.

CITY LIGHT & POWER CO., at Bentonville, Arkansas, is installing in its plant one 635-hp. Murray engine and one 260-hp. Murray boiler. The boiler will be fired by hand with Arkansas coal. This plant at present has one 210-hp., one 85-hp. Murray engines and two 150-hp. Murray boilers. The new unit will be in operation by January 1, 1927. W. J. Grimes is Chief Engineer.

AT ITS PLANT at West Carrollton, Ohio, the Miami Paper Co. has installed and successfully operated economical equipment for transferring coal from railroad cars to the boiler plant. A McMyler Interstate crane, mounted on the roof of the boiler house is used to handle the coal from the cars to the shaft which ends at the top of the building, carrying the coal to the bunkers. Previous to the installation of this crane a bucket conveyor had been used. According to Joseph McNabb, Chief Engineer of the company, the bucket conveyor formerly used averaged about $4000 a year in maintenance cost; in addition, five men were required for 24 hr. a day to operate the conveyor system. The crane has now been in operation for ten years with an average maintenance cost of $17 a year, as against the average of $4000 a year for the bucket conveyor.

THE NEW JERSEY State Department of Labor, Trenton, has adopted 10 new rules governing the use of electrical equipment and electricity in the state, effective Sept. 1. These are based on a comprehensive study of the causes of recent deaths by electric shock. One of the new rules requires the effective and permanent grounding of all motors, portable or fixed; all portable devices, such as electric controls, hand and stand lamps, portable conveyors, elevators, etc., together with all-metal enclosures, switches and other power control. Another regulation prohibits the use of balance coils, which, because of defective circuits, make possible the bypass of a current through the body of a worker who in-

advertently completes a false circuit through ground and thus receives a shock of double voltage. Another rule limits the operating voltage on artificial lighting circuits to a maximum of 125.

THE NEBRASKA UTILITIES INFORMATION BUREAU, Lincoln, has just completed a survey of 144 cities and towns covering the use of isolated power plants and central station service, with findings showing a rapid trend towards the latter character of operation during the past 18 mo. It is pointed out that in 1920, Nebraska had 528 incorporated cities and towns, more than half of which were served electrically by individual power plants. Three years later, 1923, there were 509 communities in the state using electric energy and of these 334 were dependent wholly or in part on high line service. At the present time, counting unincorporated hamlets and various organized agricultural districts, there are now more communities using electricity than there are incorporated cities and towns, and more than 400 of these rely almost exclusively on service over transmission lines. It is pointed out that interconnection between the larger generating stations of the state, connecting the plants of several of the more important companies, is now being carried out, and it is estimated that more than one-half the generating capacity of the state will be so joined together by the end of the present year.

THE UNITED STATES CIVIL SERVICE COMMISSION announces open competitive examinations for the following positions: Hydro-Electric Engineer, Associate Hydro-Electric Engineer, Assistant Hydro-Electric Engineer, with entrance salaries of $3900, $3300 and $3000 respectively. Applications for these positions must be on file at Washington, D. C., not later than October 26. Competitors will not be required to report for examination at any place, but will be rated on their education, training, experience and fitness, together with their writings to be filed with the application. Full information together with blanks may be obtained from the United States Civil Service Commission, Washington, D. C., or from the secretary of the board of examiners at the post office or customhouse in any city.

Catalog Notes

INGERSOLL-RAND CO., 11 Broadway, New York, has just issued an attractively illustrated booklet containing a brief narrative of the development of American railway motive power from its earliest days and leading up to the recent introduction of the oil-electric locomotive. Some data are given concerning the economy already effected by the latter type of locomotive, and its potential effect upon the future of railroading in America.

IN AN ATTRACTIVELY illustrated 36-page booklet, the Cleveland Oak Belting Co., Cleveland, Ohio, describes and discusses its Cleve-Oak quality belting, Cleve-Oak round leather belting, belt dressing, cement, belt fastening machines, and other products. The last few pages of the book contain interesting engineering data on strains on shafting, condensed formulas for belting, horsepower of belting and the like.

CELITE PRODUCTS CO., Los Angeles, Calif., in its new bulletin 103, describes and illustrates Sil-O-Cel insulating brick as applied to different types of furnaces. Various styles of brick are supplied for use where temperatures are below 1600 deg., other types when temperature is between 1600 and 2000 deg., and still others for temperatures as high as 2500 deg. Another special form is supplied for rotary cement and lime kilns. In Bulletin 325, the Celite Products Co. discusses the use of Celite as an admixture in concrete. Technical data concerning the effect on concrete mixes of siliceous admixtures, together with summaries of tests made by prominent testing laboratories, are given in the bulletin.

G. & G. ATLAS SYSTEMS, N. Y., describes its pneumatic tube system in an attractively illustrated 12-page bulletin.

THE MASTER BUILDERS CO., Cleveland, Ohio, has just issued a bulletin describing Dycrome, a method and material that produces by surface treatment hardened concrete floors in colors.

WASHINGTON IRON WORKS, Seattle, Wash., in Bulletin B, just issued, describes and illustrates the Washington-Estep Diesel engine. This engine is manufactured in various sizes from 50 to 1800 b.hp. in both marine and stationary type. It is of the four cycle solid injection type, and details of its construction and operation are shown in the bulletin.

ALLEN-BRADLEY CO., Milwaukee, Wis., manufacturer of electric controlling apparatus, has just issued a bulletin describing and illustrating alternating current resistance starters, Type J-1552, across-the-line starting switches and Type J-3052, automatic resistance starters for starting single and multi-phase squirrel cage motors of various sizes and voltages.

AMERICAN ENGINEERING CO., Philadelphia, Pa., has just issued its new catalog, describing the Lo-Hed electric hoist. In addition to all the previous models of this hoist, the catalog lists for the first time, six large new models which have just been added. These hoists extend the range of capacities up to 24,000 lb. All of these hoists are built for both a.c. and d.c. in four distinct classes and various sizes with various types of suspension and control.

LEAFLET 20,292 has recently been released by the Westinghouse Electric and Manufacturing Co., describing the Type MF Motor Starting Oil Circuit-Breakers. Such features as the manual operation, indoor service, non-automatic starting position, and the automatic running position are pointed out, and the application, operation, construction and engineer's specifications are discussed. Two tables, one showing the ratings for motor starting breakers, and the other listing the motor starting breakers of the type MF complete this leaflet.

PUBLICATIONS of the Engineering Experiment Station of Purdue Univ., Lafayette, Ind., are available, at a slight cost, to cover minor expenses of preparation, as follows: No. 1, Lightning Protection, by C. F. Harding; No. 3, Coefficients of Discharge of Sprinkler Nozzles, by F. W. Grove, Jr., and W. E. Stanley; No. 8, Flow of Water Through Spiral Riveted Pipe, by F. W. Greve and R. R. Martin; No. 18, Self Corrosion of Lead Cable Sheath, by F. O. Anderegg and R. V. Achatz; No. 22, Watt-hour Meter Accuracy and Temperature Changes, by D. T. Canfield; No. 25, Flow of Heat in Pistons, by H. A. Huebotter and G. A. Young; No. 26, Steaming Tests with Indiana Coals, by A. A. Potter, A. W. Cole, W. E. Gray and J. P. Walsted.